The Mineralogist:

APRIL, 1938

The Art of Gem Cutting

for the Amateur and Professional

COMPLETE

$1.00

A NATIONAL SEMI-TECHNICAL MAGAZINE
DEVOTED TO
MINERALOGY, GEOLOGY, GEMMOLOGY
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Portland, Oregon

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The Mineralogist

Devoted to
Mineralogy, Geology, Gemmology
and the Collector

THE ART *of* GEM CUTTING
COMPLETE

Dr. H. C. Dake
Fred S. Young
J. Lewis Renton

PREFACE

During past centuries the fascinating art of cutting gem stones has been more ss of a deep mystery to the layman. The aim of this work is to give the teur" gem stone cutter complete technical data on the methods employed both mmercial and "home" lapidary establishments, using, so far as is possible, implest non-technical language.

n order to gain a better understanding and knowledge of the physical, chemand optical properties of the gem minerals, the reader is urged to read tech- works on mineralogy. It is possible to produce good cabochon style cut stones o finish flat and curved surfaces on specimens without a good working knowl- of the optical and crystallographic properties of the gem minerals. In order better equipped to fashion properly a facet cut stone, the lapidarist should some knowledge of the optical properties of the minerals being worked. mercial gem stone cutters having served long years of apprenticeship and rience, are enabled to do satisfactory facet cutting work without any special ical knowledge of the optical properties of the gem stones. This "rule of b" skill, however, is subject to error and cannot be recommended to the eur. :

(Continued on Page 3)

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LAPIDARY ART

The purpose of this greatly enlarged issue devoted to the art of gem stone cutting is in response to a very wide and popular demand. At the outset it was planned to issue this work as a separate publication, but the management of THE MINERALOGIST Magazine finally determined to present same to regular subscribers, as of date, at no additional cost.

Some of the work presented here has appeared in various issues of THE MINERALOGIST Magazine during the past five years. While much of the data and equipment is new, the entire work has been rewritten and elaborated. The writers believe this to be the most modern and most complete work on gem stone cutting available.

Much of the data and some of the equipment presented has been developed in the gem stone cutting laboratories by THE MINERALOGIST Magazine. Due acknowledgment is also made to the numerous workers who have made contributions to the "Lap Wheel" during the past five years. Much of their work is incorporated in the chapters.

Owing to the splendid response and support of the advertisers appearing in this issue, the management is enabled to present the enlarged issue to the readers at no additional cost. Appreciation is extended to the advertisers in making an issue of this kind possible. This publication has no financial support from endowments or public funds of any kind. Operation dependence rests largely upon the income from advertising. It costs considerably *over one dollar* per year to print and mail twelve numbers to each subscriber. The income from advertising carries the difference. It would be appreciated by the management if reference is made to this publication when responding to the advertising appearing here.

NO DATING BACK

Wherever possible we have been more than generous in accommodating new subscribers in dating back their subscription, and sending back copies. Unfortunately this will not be possible with this special enlarged number. Some of the reserve funds of the magazine are being utilized to pay the costs of this number; hence a charge of $1.00 must be made for all single copies sold after May 1st, 1938.

Every regular paid up subscriber of date will, of course, receive this number at no additional cost. Extra large issues are being planned for the future and we hope to be enabled to present additional "surprise" packages to the subscribers.

CLIMATE CONTROL

A number of factors are known to exert their influence in controlling the climates of the earth. Carbon dioxide and aqueous vapor in the atmosphere act as thermal insulating blankets and when either or both are largely increased or decreased over great areas, the climate in general of the earth is affected.

A heavy increase of the carbon dioxide content of the polar regions atmosphere for example would increase the mean temperature several degrees, this in turn would materially affect the accumulation of ice.

It is known that during periods of wide volcanic activity on earth, large quantities of carbon dioxide and moisture are given forth. The former remains mixed with the atmosphere for a much longer time than moisture which would be condensed soon and fall as rain. The theory has been advanced that the recurring ice ages of the earth are due to the changes in the carbon dioxide and moisture content of the atmosphere.

The lapidary art of cutting gem stones, both cabochon and facet styles, has been looked upon in the past as a "trade secret" by the professional and commercial lapidarist. Previous to five years ago very little had been published pertinent to the modern methods of gem stone cutting. Some data was available in old textbooks on gemmology, but the technical methods given were obsolete and written previously to the introduction of the modern grinding wheels and abrasives.

Obviously it is still possible for the skilled artisan to produce excellent work by the use of the old and laborious methods, requiring years of practice and training. Every effort is made in this work to stress and present methods utilizing modern equipment, grinding wheels, abrasives and polishing agents.

Much of the technical data given here are the findings of the Gem Cutting Laboratory of THE MINERALOGIST Magazine, 702 Couch Building, Portland, Oregon, to which due acknowledgment is made. Some of the information given here has appeared in THE MINERALOGIST Magazine during the past five years, but considerable new and revised technic has been added. New abrasives, equipment and methods are tested and designed in the Gem Cutting Laboratory, and this information appears monthly in the magazine, together with general descriptions of gem minerals, new localities and other data calculated to be of value and interest to the lapidarist.

Acknowledgment is also made to the many lapidarists who have independently made contributions to the Gem Cutting Department of THE MINERALOGIST magazine.

INTRODUCTION

It is perhaps the general impression of the layman that costly machinery and highly skilled workmanship is a requisite in converting a rough pebble into a brilliant gem stone. This, however, is not the case, as any individual, with average intelligence and one who possesses any mechanical ability whatsoever, can learn to do very satisfactory work. Obviously cabochon cutting and specimen finishing is much more simple, compared to facet cutting. It is advised that the amateur serve a period of cabochon cutting prior to attempting facet cutting.

The working of rough minerals into useful tools, weapons and ornaments dates back for many thousands of years; the exact date being lost in the obscurity of time. It is known that man lived in the stone age for thousands of years, when the only useful tools and weapons available were those which could be fashioned from the minerals and rocks provided by Nature. At least one hundred thousand years ago primitive man first learned the art of working an edge or point on some hard mineral, to be used as a tool or weapon. Later came the development of the lapidary art for the production of ornaments.

For centuries before the Christian era the gem minerals had reached a place of importance in the commerce of the early people of the world. Agate, turquoise, lapis, sapphire, jasper and numerous other gem minerals were bartered freely as articles of commerce. But long before this, Neanderthal man, the cave dweller of France, who lived more than 12,000 years ago, had learned the art of working crystal quartz into tools and weapons, if not ornaments.

Unfortunately, the gem minerals, while generally having a hardness superior to that of modern tool steel, lack in tenacity and flexibility. Contrary to popular belief, the best quality of modern tool steel is quite soft when compared to Moh's scale of hardness to many of the common gem stones, including common quartz. Moreover, gem minerals frequently have a marked cleavage—the ability to separate readily in certain directions in relation to the crystal axis. These properties, and numerous others, require grinding, cutting and polishing methods different from those employed in the metal cutting and polishing industries.

Over 1,000 distinct mineral species are known to science, and of these less than 100 are considered as gem minerals, and of this number only about forty species are in common use in the gem trade. However, some species, like quartz, may present a very large number of varieties and sub-varieties. Some 200 or more have been described for this mineral, but all are essentially the same chemically. The minerals of the quartz family are the most common to all parts of the country and are undoubtedly the most popular with the "amateur" gem stone cutter. It is possible to build up a remarkably colorful collection of cut and polished varieties of quartz, as numerous individuals have done throughout the country, at no more cost than the effort of field trips to collect the rough material, and spare time aside from regular occupations to fashion cut gems and polished specimens.

Even a casual perusal of the history of the world will bring to light numerous references to gem stones. A study of the Bible will reveal hundreds of references to gems, many of them being held in considerable religious reverence. Undoubtedly early man cherished the possession of gem stones even in the form of water-worn pebbles, long before the development of the art of facet cutting. The ancients frequently wore a gem stone without the benefit of the lapidarist, or perhaps only a hole or a groove was drilled to enable a cord to be attached to the specimen.

The story has often been told of the opal prized so highly by the Roman Senator. He suffered banishment from his country rather than yield the gem to his Emperor. This gem was one of the most valuable opals in all history, having had a value at that time of nearly one million dollars. Later some of the Napoleonic wars were financed on funds obtained by pledging a huge cut sapphire, seized in earlier campaigns. There was a time in history when the money lenders would accept only a gem stone as security for a loan, and these were frequently pledged by the nobility. Since an enormous amount of wealth can be concentrated in the small bulk of a gem stone, it is a known historical fact that in times of world stress the investment of funds in gem stones may at least serve to protect the bulk of the principal. Obviously, interest coupons are not attached to gem stones, but funds invested in diamonds a hundred years ago would give a greater yield than some "gold bonds" which have been widely sold during this period.

Empires may rise and fall; the currencies of nations may rise and decline; paper securities and properties may decline to a point where they become worthless, but for century after century the precious gems hold their own. True, in times of "depression" the value of gem stones will decline, due to lack of demand, but the intrinsic value is always there. Nothing short of the discovery of extensive additional deposits, or the development of perfect synthetic manufactured stones, will ever affect the basic value of gems. It is inevitable that a substantial part of the newly created wealth of the world will always find its way into the gem markets for the purchase of large and valuable stones. What type of tangible wealth, other than bulky gold or silver, can point to a longer period of stability and security of principal than diamond, ruby, sapphire, opal and a host of other gems?

The investment of a substantial sum of money in a beautiful gem may at the time of purchase appear to be purely a "luxury," yet there are countless instances where these stones would later carry the owner through a period of stress, when everything else had been lost. Some famous gem stones have a history which goes back into antiquity, but we know of no instances where their value has declined to a point where they became worthless.

GEM CUTTING AS A HOBBY

As a useful, valuable and practical hobby, gem cutting is rapidly reaching a position among the major avocations of the country. For many years the art of gem stone cutting was confined to skilled artisans, who handed down the "secrets" of the trade from father to son. Often in Europe an entire family would be engaged in gem cutting, working within the confines of the homes. Even today in some of the gem cutting centers of Europe, the work is still carried on in the home of the cutter.

Until very recently, little data of a modern nature was available on the technic of gem cutting; the few books on gemmology carried obsolete data and technical methods in use prior to the introduction of the modern grinding wheels and abrasives. Researches made by various "amateurs" in recent years have made available new technic on gem stone cutting. While the purpose of this present work is mainly to present the technic of gem stone cutting from the standpoint of the "home" lapidarist, yet the methods given here are applicable to commercial establishments and find such applications.

The ability to cut cabochon style gems and to finish flat and curved surfaces on a specimen, can be acquired by any individual having even a slight mechanical skill. The first few attempts at shaping a cabochon may result in disappointment, but soon the fingers become skilled in the manipulations and good work will result. Obviously, facet cutting is more difficult and requires longer practice to reach perfection, but thousands of "amateurs" throughout the country are doing quite creditable work.

Since rough gem minerals of some type or other can be found in practically every part of the country, the "amateur" need not lack for material to work upon. The quartz minerals, for instance, are to be found in practically every part of the country. Usually good material can be obtained by merely the time and effort to visit the many localities where these minerals are to be found. Localities of this kind are described in the pages of THE MINERALOGIST Magazine and in the popular book, "Quartz Family of Minerals." Uncut semi-precious gem material is available at a very reasonable cost and can be obtained from the numerous distributors of these materials. The cost of labor in the production of a semi-precious gem is generally a substantial part of the final cost of the finished product. Numerous "home" lapidarists throughout the country have built up valuable collections of cut and polished gems and specimens, at no more cost than the utilization of their spare time.

Gem cutting is a delightful hobby. It will carry you into the field in search of material; you will learn to recognize the gems by their familiar names and become familiar with their romantic history. Your otherwise idle time can be put to good use in the creation of objects of art, beauty and value.

TYPES OF EQUIPMENT

The type of equipment most suitable for your purpose is largely a matter of determining how far you wish to carry the art of gem cutting. It is possible to finish gem stones with virtually no equipment whatever, working by hand, as is done in the Orient. Hand labor is tedious and unsatisfactory and not suited to the Occidental way of working. Foot power operated equipment was widely used at one time, and in the days of medieval gem cutting it was customary to hold the work in the left hand and rotate a lever to operate the lap with the other hand. This is why the facet cutter is sometimes shown operating with the left hand. Windmills or water power operated equipment has also seen service.

Obviously, inferior equipment or machinery that requires constant changing of wheels, buffs and other accessories will not add to the pleasure of gem cutting. Whatever equipment you may elect to purchase or construct, it is well to keep in mind the ease with which same may be operated. It is possible to conduct all operations on a single spindle, disregarding all speed recommendations, and still do satisfactory work or passable work. At a small additional cost it is generally possible to purchase or construct proper equipment and it is here advised that this be done. Investment in lapidary equipment is not necessarily a "luxury;" a well-equipped shop can turn out work having a distinct commercial value. Many "home" lapidarists manage to produce a sufficient surplus of finished gems and specimens to more than pay for the original investment and subsequent operating costs.

If you construct your own equipment a number of cast-off parts of other machinery can often be utilized. This will of course depend upon your mechanical ability to so arrange this "junk" into a workable form. Certain parts and accessories must of course be purchased, but the cost of assembling can be eliminated. Purchased equipment is quite likely to give the greatest satisfaction: it has been tried and tested by the manufacturer, and will enable you to immediately start operations.

THE ART OF GEM STONE CUTTING

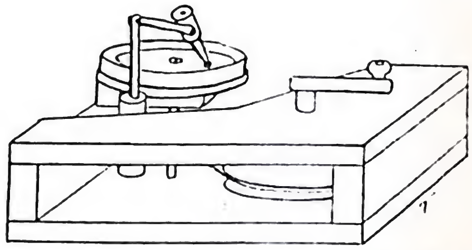
EARLY TECHNIC

The art of facet cutting gem stones is of comparatively recent development, but thousands of years ago man living in the Stone Age, worked gem minerals into weapons and tools and perhaps ornaments. The early Egyptians mined and worked turquoise and lapis into cabochon styles, over 5,000 years ago, and this probably marked the beginning of the development of the art of gem cutting as we know it today. Cabochon styles were the dominant form into which gems were worked; stones which are now cut facet were at that time often worn in the natural crystal form.

Finally some artisan discovered that some crystals could be improved as an ornament if their faces were polished. This led to the discovery that still more flash and sparkle could be had if the natural shape of the crystal was altered; and this in turn led to our modern facet cut styles. At first only a small number of facets were placed on a gem, styles which called for 16, 24, and 32 facets. Our modern standard "brilliant" cut has 33 facets above the girdle (including table), and 24 below the girdle, giving a total of 57 regularly placed flat surfaces. The diamond is generally cut into this style.

CRUDE ABRASIVES

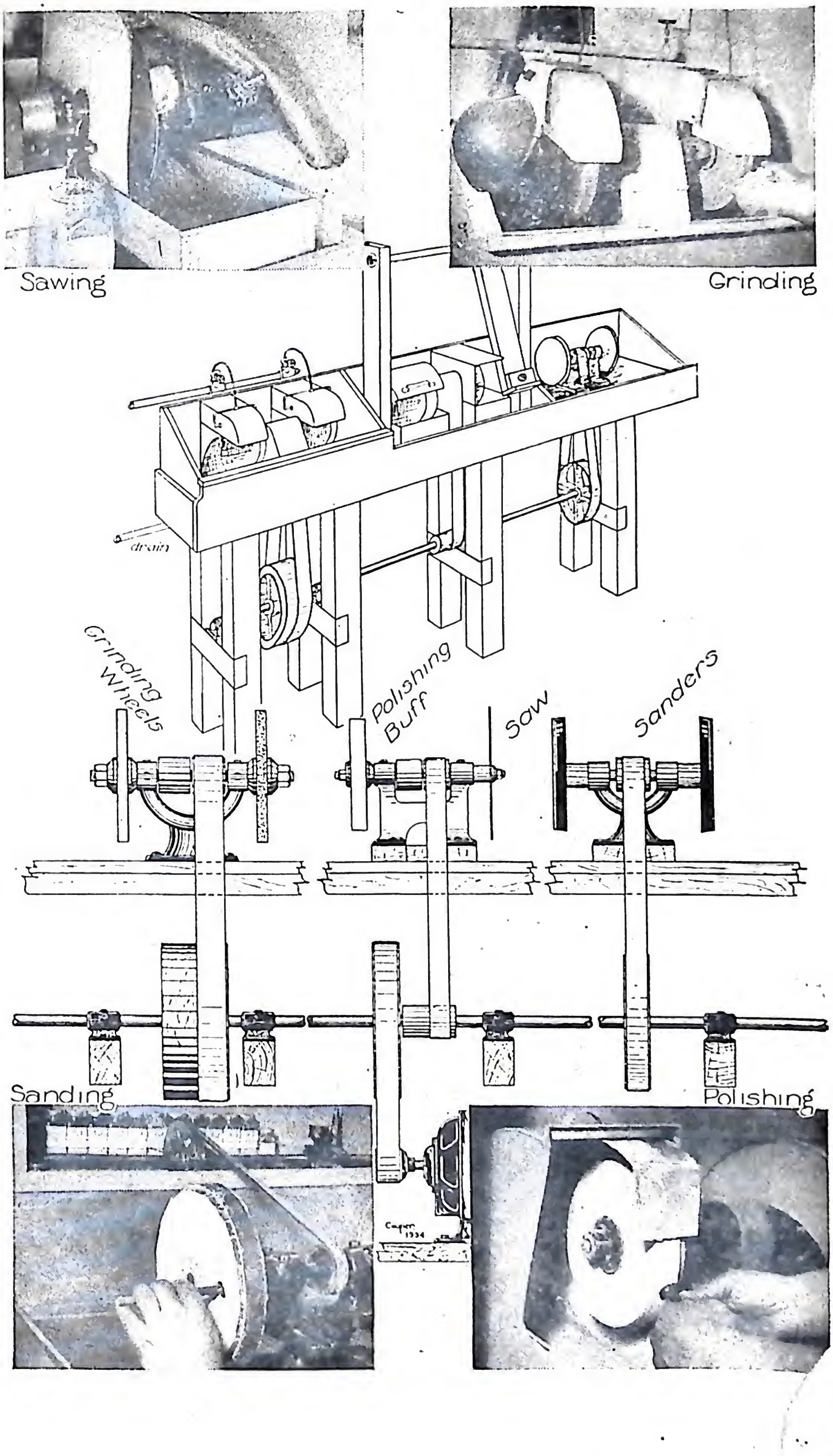
For centuries the softer gems were cut on wheels made of natural sandstone or were shaped on metal laps charged with some abrasive. There, harder stones were reduced on lead or similar soft laps, charged with emery, an impure form of the mineral corundum. There was a time in the history of gem cutting that emery was available in small quantities, from only a few localities, it was very expensive and its principal use was for this purpose. Polishing agents included various crude mineral substances like rottenstone, sand, pumice, and a number of others. Certainly the medieval lapidarist was limited in his selection of abrasives, yet by long years of experience and long hours of labor he was enabled to produce a high quality of work.



Hand-power operated facet cutting device made and used by Professor Longyear in 1895. Hand crank at right operates horizontal running lap. Professor Longyear rates as the pioneer "amateur" facet cutter in America.

Moreover, high speed machinery was unknown, the usual procedure in facet cutting was to hold the dop against the jamb peg with the left hand and turn a crank to rotate the lap wheel with the right hand. As a source of power a foot-operated lap was also in use, or the task of turning the lap fell to an apprentice. Later water-powered wheels were used for the heavier grinding of cabochon cutting and finishing larger masses.

For centuries the technic of gem cutting remained essentially the same, and what trade secrets there may have been were closely held within the family of gem cutters, and handed down from father to son. Often an entire family engaged in the art, and carried on the work within the confines of the home. This is still true at the cutting center of Idar-Oberstein, Germany, where much of the cutting is done within the home. Many of the older text books on gemmology detail the now antiquated methods of gem stone cutting. In these old works frequent references are made to the lead lap, emery, rottenstone, pumice, and similar equipment and abrasives.


Sawing
Grinding
drain
Grinding Wheels
Polishing Buff
Saw
Sanders
Sanding
Polishing

THE INVENTION OF SILICON CARBIDE

Probably the most important development ever made in the lapidary industry was the introduction of silicon carbide some forty-five years ago. Silicon carbide is a product of the electric furnace, and is available in various size grits, for lapping and sawing, in grinding wheels of different grits, and as coatings on cloth. Silicon carbide is made by various manufacturers and is sold under different trade names, including *crystolon* and *carborundum*. The electric furnace product is fused into a granular mass, the individual particles having great edge strength and a hardness equal to that of sapphire. These two properties of edge strength and high hardness lends silicon carbide well adapted as a lapidary abrasive and for grinding wheels which are fast cutting and can be run at high speeds.

Next followed another electric furnace product, the fused aluminum trioxides, sold under various trade names, including *aloxite*, *alumina* and *alundum*. This product is used in the lapidary industry as a polishing agent, and is available in various grit powders suitable for the many polishing operations.

More recently a still harder electric furnace product has been developed for commercial use. Fused boron carbide, known under the trade name of *Norbide* (Norton Company, Worcester, Mass.), is the hardest substance ever produced by man on a commercial scale. This product was developed primarily for the purpose of lapping the new and extremely hard cutting tools used in the steel and other industries. Its high hardness, ranking high enough over sapphire to cut this gem with the same ease that silicon carbide will reduce topaz, immediately suggested its possibilities in the gem cutting trade. THE MINERALOGIST gem cutting laboratories pioneered in the introduction of this new abrasive in the lapidary industry.

At the outset of the introduction of these new abrasives the lapidary industry was slow to adopt these modern improvements. This can probably be best charged to the fact that since the technic was largely looked upon as trade secrets, each worker having developed his own methods and continued to adhere to them. Very little information of a modern nature was available in the printed form until quite recently when various independent workers started the publication of lapidary technic. A search of the libraries will reveal the fact that prior to ten years ago there was next to nothing available, other than the obsolete works. Even today many gem cutters continue to use the more costly diamond dust to cut the facets on sapphire, when *Norbide*, a much cheaper product, available in standard size grits, will give equally good results with practically the same cutting speed. The same can be said of many of the other recent developments, particularly among the polishing agents.

The improved and uniform artificial abrasives are much more reliable than many of the older types of products. The modern products have served to speed up the production of gem stones and have rendered the work far less laborious, to a point where the layman with only an ordinary amount of mechanical ability can easily learn to cut gem stones, without serving long years of apprenticeship. Moreover, the technic now available to anyone will enable the beginner to follow closely in the footsteps of others who have perfected these methods which are known to give results. In shorter words, you are enabled to start correctly with proven equipment and known abrasives and polishing agents. Every gem stone cutter, including the "amateur" and the professional, will develop his own variations to suit his fancy and doubtless do equally good work; but if the basic methods given in this work are followed the lapidarist is assured of results with a minimum of effort. Equipment of any type is generally susceptible to improvement, and the suggestions given here can of course be altered to meet any special requirements.

CABOCHON GEM CUTTING

Semi-precious gem minerals, like turquoise, agate, jasper, opal and a long list of others, are usually cut rounded or flat surfaces, termed "Cabochon" styles. These may be of any shape, including oval, round, square, and rectangular. In short, there are only a few large surfaces, while in facet styles there may be 57 or more individual flat surfaces on the gem. All of these must be cut and then polished.

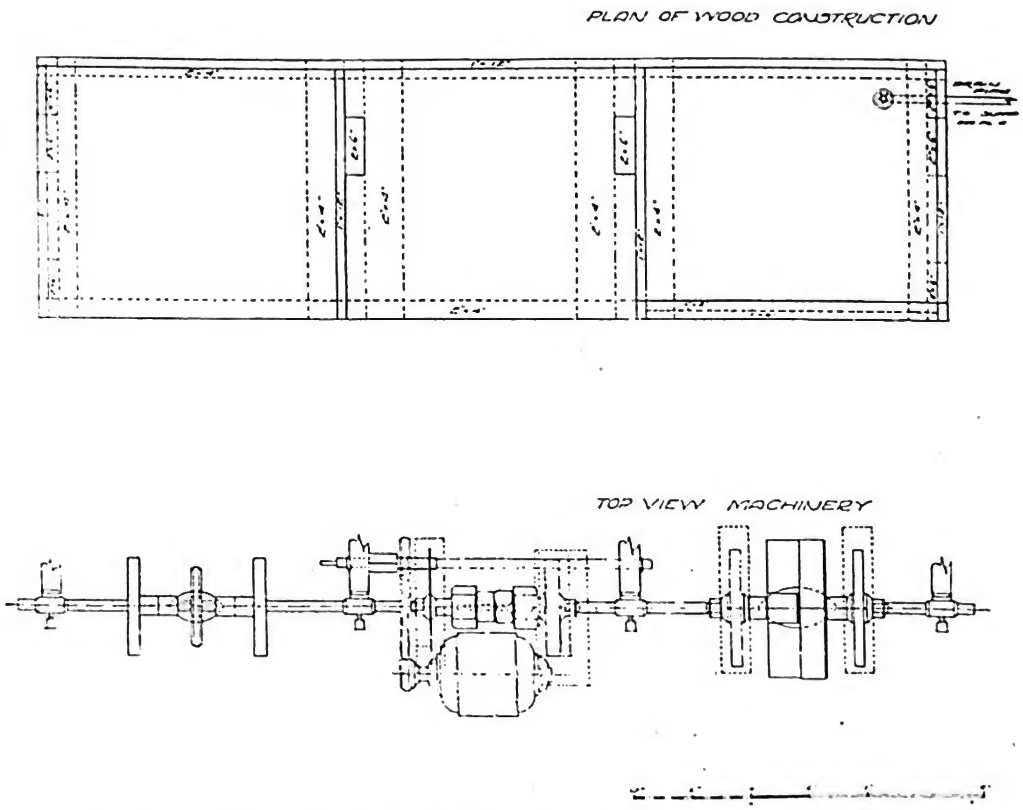
FOUR OPERATIONS

Cabochon cutting can be divided into four separate operations and most lapidary shops have special tools for each task. The rough material as presented to the gem cutting often requires reduction to the proper shape, hence sawing is the first operation, followed by the grinding wheels, sanding to remove deep scratches left by wheels and finally the polishing to give the stone or specimen a high glossy finish.

Different speeds are required for the various operations in order to get best results. It is possible to finish stones with little regard for speeds of the moving parts, but difficulties will be encountered, and it is advisable to give due regard to the recommended speeds. Silicon carbide grinding wheels will give best efficiency when run at the indicated speeds, otherwise the work will proceed slowly or the wheel surfaces will tend to develop a "glaze." Likewise, if the "mud" saw is operated at higher speeds than advised, cutting may be faster at the outset, but the disk is sure to develop "flats" and nothing is gained. Hence we urge to follow closely the indicated speeds for the various operations.

material. Some of this technic has been given elsewhere in this work. For all ordinary purposes the diamond and "mud" saws are most widely used in commercial and home lapidary shops. The hand-charged metal diamond saw is by far the most efficient yet developed, and this tool when properly used will give good service.

Diamond saws made of *Bakelite* charged with diamond grit are available in sizes up to six-inch diameters. These are very useful where large



Plan No. 1. Showing details of construction of woodwork and machine layout for large commercial equipment shown in full page plate on Page No. 7

SAWING

Small fragments or pebbles need no preliminary sawing, and the work can start directly on the silicon carbide grinding wheels. It is possible to break a large mass and thus obtain suitable sized fragments for cabochon cutting; but this is usually wasteful. If the material is worth cutting, it is also worth sawing and thus conserving. There are several methods of sawing or sectioning

amounts of small sectioning work are done. On the other hand, these saws are costly, since they are heavily charged with diamond grit. The small diamond saws of this kind are operated at very high speeds and will section very hard gem materials like sapphire with the same ease and rapidity as a wood saw will cut hardwoods.

The hand-charged metal diamond saw has some obvious disadvantages, but it is the best tool available at present, and until some more efficient cutting disk of a large size is developed this method is perhaps the best. In all probability with the increasing demands for an efficient and yet reasonable priced sawing disk, a tool will be developed which will replace the present hand-charged diamond disk.

MUD SAWING

For ordinary lapidary work a ten or twelve-inch metal disk is used for the "mud" saw. Armco or auto steel fender iron makes an excellent sawing blade. A 20 gauge thickness will serve for a larger blade, while 22 gauge can be used on an eight-inch diameter disk. Some workers prefer the use of bronze or copper blades, but these appear to have no special advantages other than higher cost. It is suggested the saw disks be purchased from sheet metal dealers, so the disk will be true at the periphery as well as the arbor hole. In ordering disks for mud or diamond sawing, be sure to specify the arbor hole size. Three-quarter-inch is usually standard. A ten or twelve-inch blade should be run at around 300 R.P.M. Smaller blades faster in proportion and larger blades slower, so as to get the correct peripheral speed.

The "mud" saw is not "charged" with the abrasive like the metal diamond saw. The former tool depends upon its cutting ability from the abrasive grit which adheres to the blade as it passes slowly through the mixture of silicon carbide and water. The "mud" mixture consists of silicon carbide grit No. 120 mixed into a thick paste with water. Some operators prefer oil, but the latter mixture is more messy and seems to have no advantage. The abrasive mixture is kept in a metal container below the saw, with the edge of the blade passing through the "mud." Silicon carbide grit has a high specific gravity (over 4) and thus tends to settle out of the water. To give the mixture greater viscosity, some prefer to add fine clay or flour to the mix, to suspend the grit and enable same to adhere to the disk.

Fresh abrasive grit should be added to the mixture from time to time. Small amounts of the new hard abrasive *Norbide* (grit No. 120) added to the silicon carbide mixture will increase the speed of cutting. Most mud saw operators are now adding *Norbide* to the silicon carbide grits. The saw blade should be shielded to prevent splashing.

In using the mud saw the work should not be held by hand (except small fragments), but should be held in some

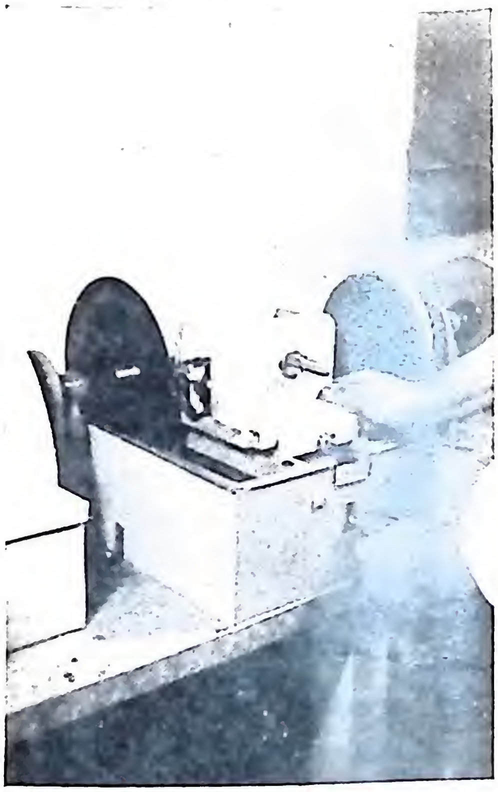
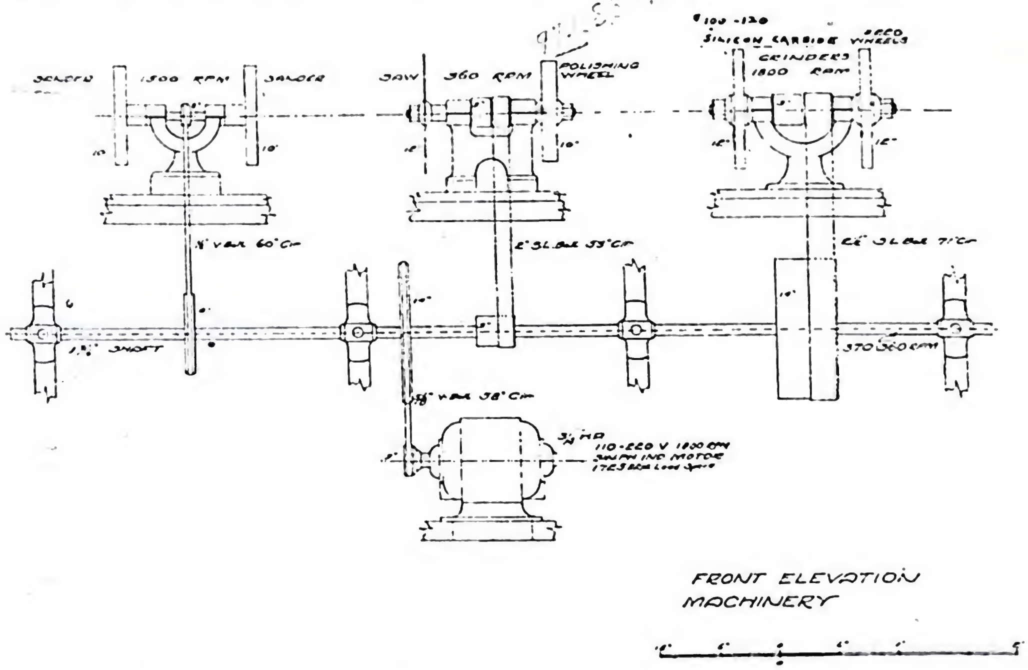


Fig. A. (Bench No. 1) Arrangement of diamond saw compartment. "Saw mill" type of carriage, stone is clamped in wooden carriage jaws, with an equivalent thickness of wooden blocks on opposite side to keep clamping face level. A heavy wing nut gives ample leverage to clamp work rigidly in position. Small wing nut at bottom enables movement of carriage sideways for additional cuts of any desired thickness.

type of mechanical arm or carriage, as shown in the various illustrations. There are several types of mechanical holders, including the swinging arms and the saw carriages. The newly developed sawing carriages are superior to the swinging arms and similar methods. For one thing the saw carriage holds the work more rigidly and does not permit side movement. Often in diamond sawing the flange on one side of the saw may be quickly lost, due to the work not lining up true with the arbor and blade. The saw will then tend to travel off at an angle, or, in the case of the mud saw, binding will result when sawing thick specimens. Moreover, the sawing carriages enable the operator to clamp a much larger mass into proper position.

After the work has been clamped into proper position, and the saw has worn a groove in the work, tension is then applied to the arm or carriage and the work proceeds without further special attention. As the saw cuts deeper slightly additional pressure can be applied. A system of weights and pulleys or spring tension can be used. While it is customary to run both the mud and diamond saw in the vertical position, we know of at least one prominent "amateur" who has done an enormous amount of work during the past ten years on the mud saw operated in the horizontal position. Mr. William Pitts of Sunnyvale, California, uses this method and finds it effective. About ten pounds tension pressure is applied when sawing a four-inch specimen with a twelve-inch diameter disk.

A little experimenting will enable you to adjust the proper tension of the work against the blade, as well as to get the correct speed. High speeds tend to throw the abrasive from the blade; and, after all, the cutting is directly dependent on the ability of the disk to carry the mixture to the point of cutting. Low speeds also present some disadvantages. Mud sawing is very much slower compared to the diamond saws, and as a rule once the operator learns the use of the diamond saw he will abandon the mud saw, except for sectioning very large specimens.



Plan No. 2. Dimension details, front elevation of machinery for large commercial equipment shown in full page plate.

DIAMOND SAWING

The hand-charged metal (disk) diamond saw is the prime favorite with most lapidarists and is to be found in practically every lapidary establishment, both commercial and private. This tool is operated at the same speeds as the mud saw, but is a far more delicate cutting blade, giving long and excellent service if properly charged with diamond grit and operated correctly.

The hand-charged metal diamond saw must be operated with proper lubrication, by passing the saw through a mixture of equal parts kerosene and automobile lubricating oil. The lubricant is held in a shallow metal reservoir below the blade. Only the edge of the saw need pass through the oil. Like the mud saw, this tool should be shielded with sheet metal and a cloth cover to prevent splashing. Generally a twelve-inch disk is operated at about 300 R.P.M.

Armco or auto steel fender iron will make an excellent disk, but some workers prefer bronze, copper or other metal. Disks of this kind can be purchased ready cut at a nominal cost, and if properly operated they can be recharged an indefinite number of times. If the disk meets with an accident and is badly bent, discarding is indicated. A bent saw blade will tend to travel "sideways," thus increasing friction and tending to tear out the diamond grit embedded in the periphery. If the disk does not have a proper flange or "set" on each side of the cutting edge, tendency to travel sideways will be noted.

The inexperienced lapidarist will no doubt have some difficulty in properly charging and using a diamond saw at the outset, but a little experience and observation will soon correct improper use. Many home lapidarists find it advantageous to purchase diamond saws ready charged from the manufacturer. The amount saved by charging disks is not great if time be considered. Moreover, the manufacturer purchasing diamond bort in large quantities naturally gets wholesale rates.

The following outline is the technic used by many lapidarists in charging the metal diamond saw: (1) Mount the disk on arbor and make certain the periphery runs true. A sharp fragment of agate held on a rigid rest will serve to trim the edge of the disk to run true. (2) If disk tends to wobble when running, a heavy hardwood flat stick can be used to slightly bend and "massage" the blade to largely eliminate the side wobble. Both these operations are carried out while the saw is in motion. Most manufacturers place a slight "dish" effect on the saw, and indicate the direction the blade should be run. The reason for the "dish" effect is to hold the saw under tension, as clamping will eliminate the "dish."

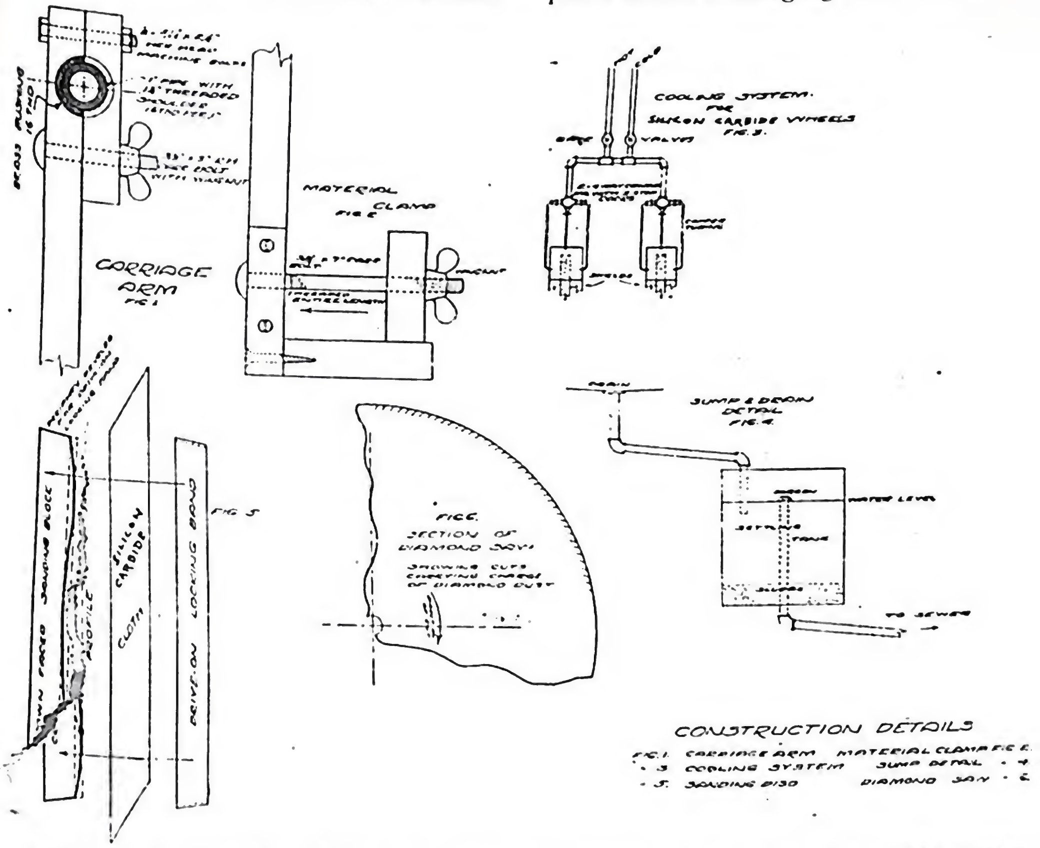
(3) The periphery of the disk is then notched at intervals of about one-sixteenth inch, making the notches about one-thirty-second of an inch deep. A suitable tool for this purpose is an old hacksaw blade ground to a dull chisel shape edge. The edge should be left slightly dull or about .003 inch thick. Use a light hammer to drive the blade into edge of saw. (4) Diamond bort is then mixed with a bulk of vaseline about the

SAWING

Fig. B. (Bench No. 1) Diamond saw with upper part of shielding in position. Cloth splash curtain thrown back to show carriage in position with work clamped in place. Cloth curtain dropped down when saw is in operation.

size of a pea. Two carats of crushed bort should be used to charge a twelve-inch blade. Other disks in proportion. A smaller amount of diamond can be used, but since the efficiency of the blade is wholly dependent upon the amount of abrasive worked and held in the periphery, it is obvious that skimping on diamond is not a saving. Grit can be purchased ready crushed from dealers. Number 100 or 120 grit is generally used. Some workers prefer to use a coarser grit.

(5) The diamond paste is then applied to the notches with a toothpick pressed in between the notches and the openings closed by light tapping with a peen hammer. The skill with which the worker can close the notches of the saw and thus grip the fragments of diamond will largely determine the efficiency of this tool. (6) The saw is then placed in motion and a special grooved steel roller is run on the edge of the saw to further



Plan No. 3. Dimension details for construction. Swinging arm for sawing, water system, etc. For large commercial equipment shown in full page plate.

close the notches. The steel roller should be held steady on a rigid rest. This operation also gives the saw its proper "set." Without this the cutting blade would tend to bind and not cut its clearance.

Some operators use a copper diamond saw and merely smear a small amount of the diamond paste on the edge of the blade. This method is effective so long as the abrasive remains at the point of cutting, but the method is wasteful, especially in sectioning large specimens. A little experience is needed to properly charge and operate a diamond saw, but with proper use a well charged blade, twelve-inch diameter, will section at least 1,000 square inches of hard material like agate. Some saws will sometimes give as much as 5,000 inches of service, but eventually the fragments of diamond will be lost from the metal and the speed of sawing will be gradually reduced to a point where recharging is indicated.

The diamond saw has been condemned by the inexperienced, generally through improper use. The diamond saw will cut at least four times faster than the mud saw. A heavily charged blade will even exceed this comparison. We know of one instance where a properly charged blade was purchased from a reliable manufacturer; the blade was set up to run at the speed of a wood saw and operated without any lubrication. Needless to say this experiment was a complete failure. Hence, before you condemn this tool make certain your technic is correct.

Large specimens should, of course, be held in a rigid clamp, either the carriage or swinging arm type or some similar effective means. The carriage or arm should be in line with the saw and arbor, otherwise the tool will tend to cut sideways. If the "set" on one side of the saw is worn off regularly there is likely something out of correct line. Do not start a cut on the face of a sharp edge of hard material. Use very gentle pressure until a groove has been worn and then pressure can be applied, as explained under mud sawing. Some gem materials will cut faster than others. For example, sawing opal or obsidian a diamond saw will give a great deal of service. On the other hand, hollow quartz crystals are severe on the tool. A fragment of quartz crystal may become wedged in the cut and damage the blade.

Most commercial shops use an eight or ten-inch saw, fitted with a rigid hand rest, where the "resawing" is done after the material has been reduced to slabs by the large tool. The "resaw" is very useful for production of cabochon stones in quantity.

For sectioning very small fragments of gem material like valuable sapphire, a small diamond saw can be made from the lid of a tin can. A thin disk of this kind two or three inches in diameter will prove effective if small amounts of diamond paste are applied at the point of cutting. The work is held by hand on a rigid rest. The advantage of the very thin disk would be in economy of a thin cut and thus conserving valuable gem material. Precious opal is sometimes sectioned on a saw of this type. The small diameter *Bakelite* diamond saw (Norton Company) is very effective in sectioning small hard gem fragments. A saw of this kind would last indefinitely and prove economical in the long run where valuable material is handled frequently. Diamond charged *Bakelite* saws of this type sell from approximately $18.00 to $75.00.

GRINDING

Grinding wheels find constant use in the lapidary industry for shaping various cabochon styles, for roughing out material prior to facet cutting and for working down the face of specimens. The grinding wheels in most universal use are the silicon carbide wheels sold under various trade names, including *Crystolon* and *Carborundum*. Sometimes these wheels are termed "emery," but emery (an impure form of the mineral corundum) has now largely given way to the modern product of the electric furnace—silicon carbide.

GRINDING WHEELS

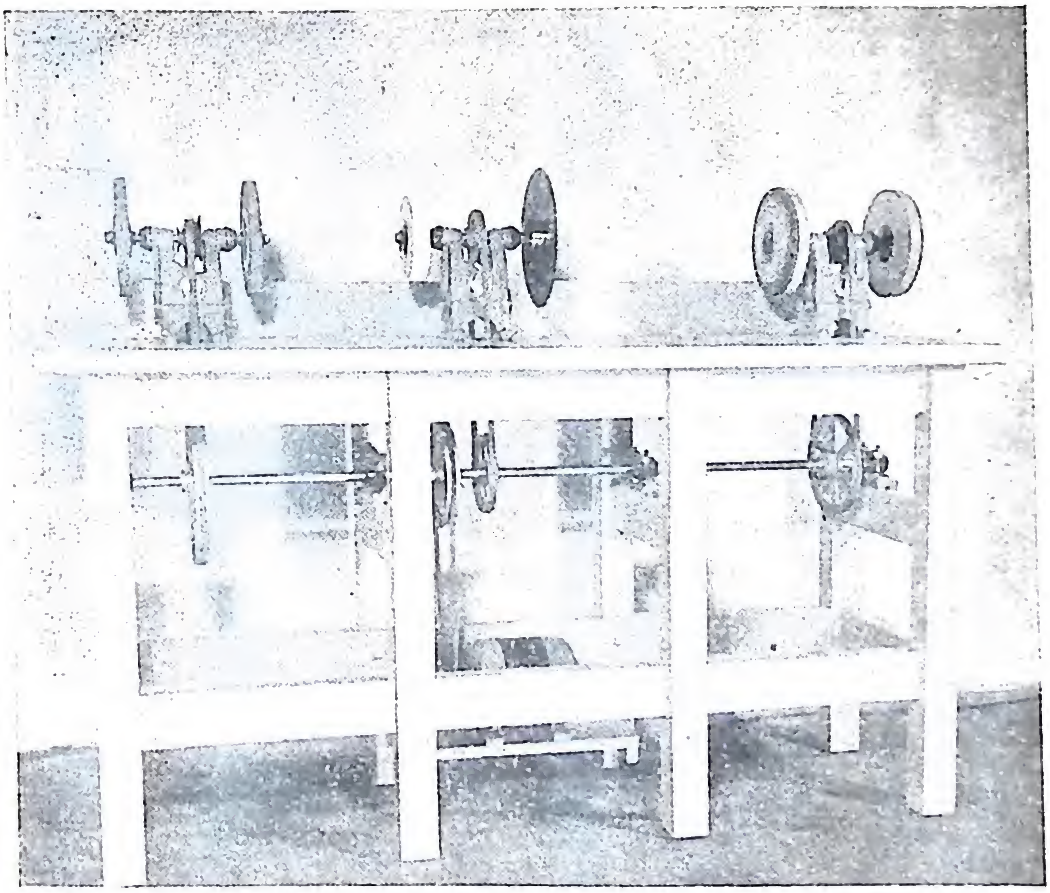
Fig. C. (Bench No. 1) Two eight inch grinding wheels operating in water. Stones (cabochon are first roughed out on No. 100 grit wheel at left, and finished on No. 220 grit wheel at right.)

The periphery of wheel should not be permitted to remain submerged for a long period of time when wheels are not in operation. A petcock is placed at left side of water reservoir to permit operator to quickly lower water level, when unit stands overnight or for longer periods. Lower portion of wheel saturated with water and suddenly operated may throw wheel out of balance.

The effective speed of the grinding wheel is a *surface speed* of approximately 5,000 feet per minute. Thus a speed of around 1,775 would be correct for a ten or twelve-inch wheel. If the grinding wheels are operated at slower speeds cutting efficiency will be greatly reduced. Very high speeds are, of course, dangerous and mean very rapid wheel wear. The arbor diameter for a large wheel should be one inch shafting. The practice of mounting a large wheel on a very small arbor is fraught with danger.

the cabochon. Soft gems like opal and malachite can be worked wholly on the finer grit wheel. Soft materials of this type will show practically no wear on wheel.

These wheels must be operated with running water, in amounts sufficient to keep them wet. Water can be fed to wheels by small copper tubing pipe. A drain should be provided in the wa-



COMPLETE LAPIDARY UNIT

Bench No. 1A. Amateur lapidary bench with shielding removed to show machinery arrangement. The unit is 5 feet 7 inches long by 20 inches wide, light weight and freely portable.

Driver Ball Bearing (3½ inch) bench grinder is driven from line shaft shown below. For quiet operation the line shaft is mounted on four ball bearing pillow blocks and coupled to a 1/3 H.P. electric motor, by floating power. The weight of motor is ample to maintain proper belt tension.

Grinding heads are equipped with two eight inch silicon carbide grinding wheels (100 and 220 grit). One 6x1 inch rock hard felt polishing buff, one 12 inch diamond saw, and two six inch silicon carbide sanding disks. Correct speeds are given to each operation by the use of proper size pulley on the line shaft as shown in above illustration.

Two grinding wheels are generally mounted on the arbor, one on each side. A No. 100 grit wheel can be used for the roughing out and fast cutting, and a No. 220 grit for the final shaping of

ter-proof grinding compartment. The wheels, of course, are shielded to prevent splashing. As an alternative to circulating water for the grinding wheels, for smaller units, a water compartment is provided. The wheel is run with the edge in water. Properly designed units of this type give complete satisfaction.

Silicon carbide wheels are made in various grits as well as "bondings." It is important to use the correct bonding. A wheel suitable for metal grinding may be wholly unfit for mineral and gem work. A hard bonding will generally mean wheel economy, but slower cutting, while a very soft bond may cut fast but show an alarming amount of wheel wear. If you purchase grinding wheels from dealers in lapidary supplies and abrasives, you can obtain the proper bond wheel. The hardware supply man may not be familiar with the requirements of the lapidary industry. The Norton Company booklet, "Abrasives for the Lapidary" (free, from manufacturer), shows the proper bondings used for gem stone cutting.

In all grinding operations the work is held against the periphery of the wheel, using a rest for the forearm and elbow to steady the work. Most of the fashioning of cabochon stones is carried out on the periphery of the wheel. The sides of the wheel are used to flatten the base of a stone, or for grinding flat surfaces on specimens.

SANDING OPERATIONS DISKS AND DRUMS

After the stones or specimens have been properly shaped on the grinding wheels, it will be necessary to remove all deep scratches prior to polishing. Cabochon gem stones are generally "sanded" to remove all deep scratches. Large, flat surfaces can be best prepared for polishing by first lapping on the horizontal running lap with fine grit abrasive. This technic is described elsewhere in this work.

The "sanding" operation is an important one and one of the most difficult to master, simple though it may seem. It is possible to obtain a semi-polish on a stone with little or no sanding, but work of this type held in close comparison with properly polished examples will immediately stand out in glaring contrast. Deep scratches will not be removed by the polishing agent, hence these defects will stand out against the otherwise polished surface. A gem worth cutting should be worthy of a proper polish, and a collection of highly polished stones will stand out in contrast to one done carelessly.

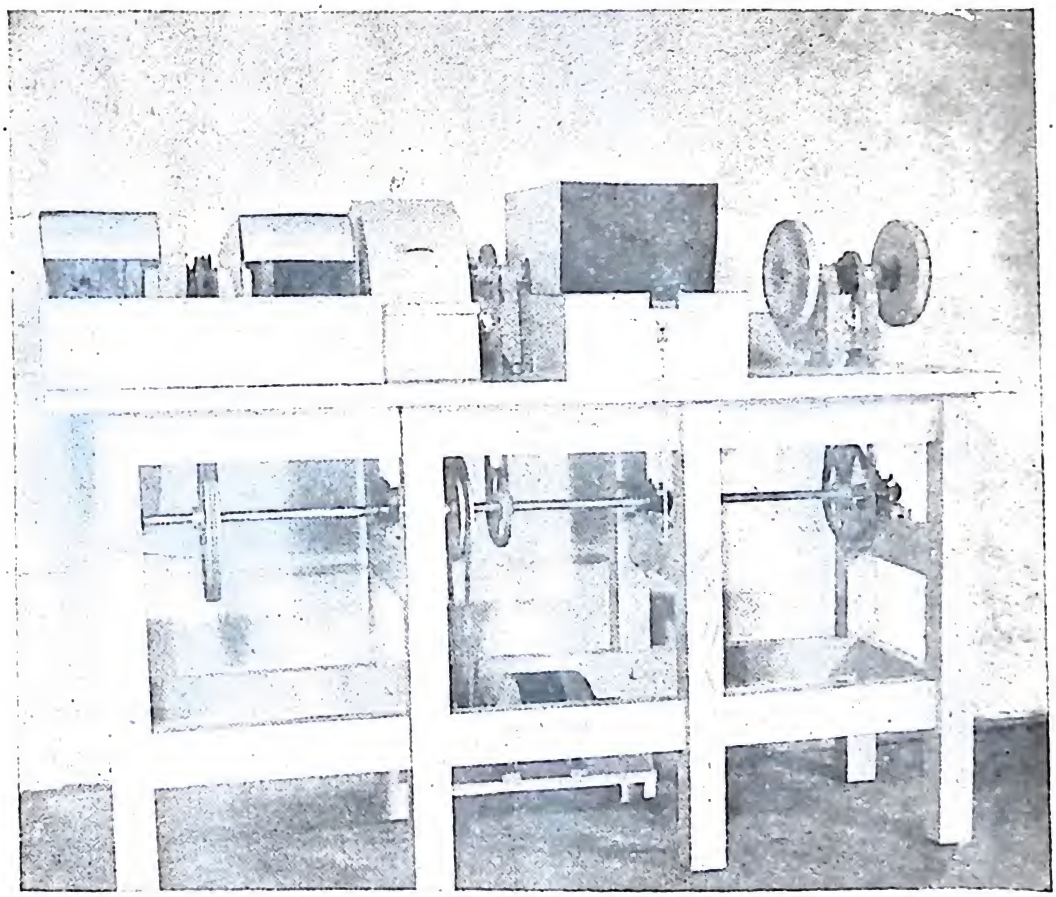
There are two types of sanders in general use. The vertical running disk type of sander is used for finishing cabochons and the smaller flat surfaces. The drum type of sander is not recommended for cabochons, but is widely used for large flat surfaces. The drum type of sander is described elsewhere and shown in the illustrations.

SANDING

Fig. D. (Bench No. 1) Sanding — removing scratches prior to final polishing. Two ten inch maple disks covered with silicon carbide cloth. See text for technic of sanding and other operations of complete bench unit No. 1. A ten inch vertical running sanding disk should be operated at approximately 1,200 R.P.M.

The vertical running sanding disk is made of wood and covered with silicon carbide abrasive grit, generally No. 220. The sanding operation can be looked upon as a form of dry lapping, as this operation is done dry. To better enable the lapidarist to handle the cabochon in the sanding and polishing operation, the stone is first dopped by mounting on a stick as described under "Dopping the Gem." The vertical running sanding disk is made of wood, with about a ten-inch working face. The wooden disk can be about 1¼ inches thick with a slightly tapered periphery to permit slipping on a metal hoop to hold the abrasive cloth in position. The working face of the disk should be slightly convex, about ¼ inch higher in the center and tapering off at the periphery. The sander will operate better if a ¼-inch thickness of felt, carpet or sponge rubber is cemented on to give a soft base for the sanding cloth. The most effective speed of the sander will be from 1,200 to 1,500 R.P.M. for a ten-inch disk. Other disks, including the "drum" types in proportion of smaller diameters should operate at higher speeds to obtain the correct surface foot speed.

Each individual will develop his own technic of sanding. The correct method is to use a brushing movement and turning the stone constantly so all areas will come in contact with the sanding cloth. If the stone is held in a fixed position with heavy pressure, the tendency will be for additional scratches to develop. Do not unduly heat the stone, for this may soften the dopping cement. Most operators use two sanding cloths;



COMPLETE LAPIDARY UNIT

Bench No. 1B. Amateur lapidary bench showing shielding in place. Water connections are not needed for this unit. The pans shown below the grinding wheels (at left) are especially designed with a series of baffle plates to enable operation of wheels with periphery running in water. A perfect and proper distribution of water is maintained with no outside splashing. Provision is also made to keep wheels immersed as they wear to smaller diameters (see illustration "Bench No. 1A").

Diamond saw is fitted to operate with saw mill type of carriage, built into the oil pan, lined with tin, and readily removable for cleaning, etc. Spring tension is maintained on saw by adjusting chain shown hanging in front of saw compartment.

one mounted on each side of the arbor, and one carrying a fresh and the other a well worn cloth; the first part of the sanding being carried out on the newer cloth and finishing on the well worn cloth, prior to passing to the final polishing buffs.

FINAL POLISHING

The final polishing of cabochon gems, flat and rounded surfaces, and similar work, is generally carried out on a felt buffing wheel. Leather polishing buffs are also used for some gems and are preferred by some cutters. Cloth and muslin buffs are sometimes used to polish very soft gems like malachite or calcite.

The speed of the felt polishing buff is approximately the same as for sawing. Hence, in small units the polishing buff can be attached to the sawing arbor. Like in all other lapidary operations, care must be used to avoid contaminating the polishing buffs with abrasive grits. Moreover, only one type of polishing agent should be used on a buff. Separate buffs must be kept for each polishing agent. This is very important and should be observed, for, after all, the buff will be effective only for the coarse polishing agent and not the finer one which may be mixed in later.

Many lapidary shops maintain two or more polishing buffs, each used for some separate or special polishing agent. There is a difference in the degree of polish seen on various gem minerals; the harder the material the higher the final polish. The laboratory of THE MINERALOGIST Magazine is often asked to give an opinion on the possibilities of polishing very soft material like calcite. It is impossible to obtain a very high glossy finish on very soft materials, especially if they tend to be slightly porous, fibrous or granular. Hence it is not possible to obtain as high glossy a finish on a soft substance, comparable to that seen on a very hard gem. In the case of soft and granular materials, a finishing gloss can be given (after polishing) by one of the varnishes (Dakes varnish) recommended for this purpose.

In any case do not attempt to polish a stone until all deep scratches have been removed in the sanding or lapping operations. Polishing is not a long and tedious process, provided the surface has been properly prepared. A cabochon of agate can be polished in a few minutes by proper technic. Some gem stones like opal will be greatly enhanced if given a high glossy finish, lending an illusion of "depth" to the stone.

Various sized felt buffs can be used, the size advised for the home lapidarist being about 1x8 inches, "rock hard" type. Commercial shops use large sizes, usually about 3x16 inches. Both sizes should have an approximate peripheral operating speed of 900 *surface feet per minute*. Note: This differs from R.P.M. (revolutions per minute of the arbor).

A very wide variety of polishing agents have been used in the lapidary industry. Prior to the introduction of the modern polishing agents, materials like pumice, chalk, sand and rottenstone were the only materials available. Materials of this kind are effective and can be used, but the graded and manufactured polishing agents are much more uniform and reliable. Further, the manufactured powders will be found free of objectionable coarse grits, which may give trouble in the cheap and ungraded agents.

The *Alumina polishing* powders manufactured by Norton Company are very satisfactory for gem polishing. These are available in various grades to fit all needs of gem stone polishing (other than diamond). Norton *Alumina* E-67 and E-111 are satisfactory for general polishing, while the *Levigated Alumina* is excellent for obtaining a final high glossy finish. These polishing powders should be used on separate buffs.

Dixon & Company market *Damascus Ruby Powder*, a polishing agent widely used for polishing facets on gem stones. Dixon & Company also stock a wide range of other polishing agents.

The *Final Polishing Agent*, marketed by Waldru Lapidary Shop, has been tested and described in THE MINERALOGIST as a satisfactory general polishing agent.

Tripoli powder and tin oxide powder also find use in cabochon polishing of various kinds. The tripoli will give a good polish on most hard materials, while tin oxide is frequently used to apply a final high glossy finish. All the polishing agents referred to above are generally used mixed with water into a thick paste and applied to the buffs with a brush. Again we repeat: Do not use more than one polishing agent on a buff. Keep separate buffs and containers for each.

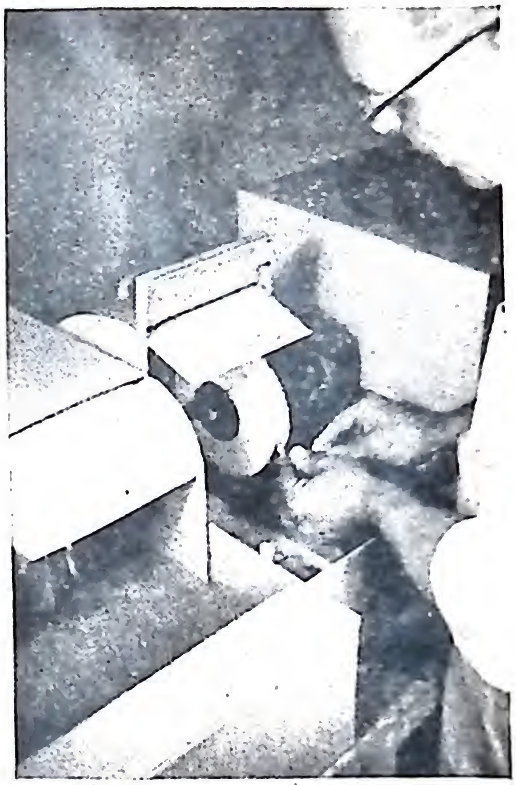
CUTTING STAR SAPPHIRE

Asterated sapphire must be cut cabochon style, and since this material has a high hardness, some special problems in sanding and polishing are presented.

The rough pebble or crystal must first be properly oriented in relation to the crystal axis. The star will appear only when the rounded cabochon surface is in the plane of the A axis, and at right angles to the principal C axis. A sapphire crystal is usually prismatic and elongated, with the C axis running lengthwise in the crystal. The rough crystal or pebble can be quickly reduced on a silicon carbide wheel, the "J" bond will cut fast. Generally the back of the cabochon is made slightly convex and is left smooth but not polished. It is said that polishing the back would in some cases detract from the appearance of the star, but this does not seem probable in the light of the recent researches of Dr. A. J. Wolcott of the Field Museum. According to Dr. Wolcott the asterism in the sapphire is due to the diffraction phenomenon caused by inclusions of microscopic sized crystals along certain planes of crystal symmetry. Hence, it would appear that reflection would have little to do with asterism and an opaque "backing" is not needed to bring out the star. All opaque or slightly opaque sapphires do not necessarily show a star, and there are no external indications to show if one is present. Actual cutting seems to be the only way of revealing the possible presence of this effect.

To remove the scratches left by the grinding wheels, vertical running sanding wheels are used. The cloths are charged with No. 220 grit silicon carbide. Some lapidarists pass from the No. 220 to a special sanding disk charged with No. 500 *Norbide*, to save time later at the polishing buffs. *Norbide* coated cloths are not available, but same can be readily made by the silica of soda methods described elsewhere.

Polishing of the gem can be done on a "rock hard" felt buff, but a leather buff will function faster. Various polishing agents are used, including tripoli, alumina, buffing powder (Carborundum Company), and very fine grit *Norbide*. No matter what polishing agent is employed this operation will be slow, as sapphire has a very high hardness.



FINAL POLISH

Fig. E. (Bench No. 1) Rock hard felt buff wheel 1x6 inch, used for placing the final polish on cabochon cut gem stones. Felt buff can also be used for polishing specimens. The sheet metal pan below polishing buff holds the polishing powder, mixed with water, and applied to the buff with a small stiff brush.

HINTS ON POLISHING

Crocidolite ("tiger's eye") is not especially difficult to polish when cut cabochon, but large, flat surfaces present problems, since the material is fibrous and tends to "pull" out. In handling a flat surface on the grinding wheels, use the side of the wheel in the final stages of grinding to obtain a flat surface. The grinding should be done at right angles to the direction of the fibres.

Sanding should be done with light pressure. Some workers prefer to lap the flat surface on a horizontal running iron lap, finishing with a fine grit (No. 500 or No. 600) silicon carbide. Polish on a "rock" hard felt buff and finish on a medium hard felt buff. The first polishing operation can be done with tripoli, alumina, buffing powder, *Waldru* Polishing Powder, or similar polishing agents. The final polish is done with *Levigated Alumina* or tin oxide. All polishing should be done at right angles to the fibres.

Turquoise—In shaping turquoise, the finer grit silicon carbide wheels can be used to best advantage. This material is quite soft and can be cut rapidly on a No. 180 or No. 220 grit wheel, with practically no wheel wear. A coarse grit wheel may cut beyond the point intended by the operator. In fashioning turquoise, study the rough stone. Some specimens appear better if a small amount of matrix is left at certain points. Polishing can be done on a soft or medium hard felt buff, using Levigated Alumina, tin oxide or any other soft polishing agent. Some cutters use a cloth or muslin wheel charged with red stick rouge to obtain the final polish on turquoise. In all technic, the final polishing stages are done by permitting the buff or cloth to run "dry," using care to avoid unduly heating the stone. Turquoise from various localities will differ slightly in hardness and texture, but by studying the material the proper technic can be developed.

Opal—Commercial cutters handling valuable opals generally use more than one buff in the final polishing of this gem. The usual polishing agents are first used and the final high glossy finish obtained with Levigated Alumina, tin oxide, rouge and similar materials. Only light pressure is used in the final polishing stages. The high glossy finish appears to give depth to the opal, and this cannot be obtained by the use of agents like tripoli.

Malachite—Soft gem minerals like malachite (see table of hardness) will give trouble if an attempt is made to finish them in the same manner as hard gems. For fine malachite gems and specimens the cloth wheel made of muslin will give an excellent final finish. Little polishing agent is needed in the final operation and the cloth should be run quite dry.

In the use of polishing buffs and cloths, do not use more than one type of polishing powder on a wheel. Keep a separate one for each polishing agent, and protect these from grit when not in use. Obviously a coarser grit can be used on a buff which has once been used for a finer polishing agent, but the reverse would not hold true. It is impossible to get good results in polishing if all polishing agents are used indiscriminately on the same buff or cloth.

POLISHING SOFT STONES

It is a well-known fact that the ability of any substance to take a high glossy polish is directly in proportion to its hardness and compactness. A gem mineral may have a sufficient hardness and yet if its structure is fibrous, laminated or not compact, it may be impossible to secure a satisfactory polish. There is also a physical limit to the degree of polish which may be attained on the softer gems.

As a general rule the soft gems are more difficult to polish, compared to some of the harder minerals. For instance, turquoise, malachite, onyx and gypsum (alabaster) may show a "grained" appearance when polished on the usual hard felt buff. The hard felt buff with the usual polishing agents may be used for the preliminary polishing, but the final finishing can be best carried out on a softer buff of some type. Levigated Alumina, tin oxide, chromic oxide, optical lens finishing powders, whiting and rouge find use in the final polishing of soft gem stones. Soft muslin or cotton cloth buffs, run at high speeds, are often effective in applying a gloss or burnish on soft stones. Light pressure and very little abrasive should be applied in the final operation. In the marble polishing industry a solution of oxalic acid is used with the polish agent, but this substance is also used for its bleaching and surface cleansing powers.

A soft surface lacking in compactness may be greatly improved by applying a thin coating of *Dake Varnish,* after carrying the polishing operation as far as is possible. The varnish tends to fill in the shallow scratches, pits and similar surface blemishes.

A small electric motor with a speed of approximately 3,600 R.P.M. is handy for some special cabochon polishing work. The small buffs used by jewelers and dentists for polishing soft metals are quite effective for some lapidary uses. The small size buffs, felt wheels and similar accessories are inexpensive and one can be kept for each polishing agent. A threaded attachment is fitted to the end of the electric motor armature shaft, to enable the quick and easy change of accessories. Small grinding wheels can also be used with the proper attachment. A one-sixth or one-eighth horsepower will be ample, provided the speed is near 3,600 or over. Most of the special polishing done by this equipment is carried out dry or nearly so; hence, care should be used, as the friction develops heat quickly.

MINERALOGICAL SOCIETY OF SOUTHERN CALIFORNIA
Field trip sponsored by Society to enable members to collect mineral specimens and gem cutting materials. Field trips of this kind are sponsored by most of the sixty or more earth science organizations throughout the country.

SOFT FACET CUT GEMS

While ordinarily gems having a hardness of less than six are not cut into facet styles, there are some exceptions to the rule. Opal and hematite are sometimes cut facet, and these gems, varying in hardness, may be less than six. Glass, sphalerite and apatite, among other soft stones, are also cut in facet forms. Often some of the translucent varieties of opal are attractive when facets are placed above or below the girdle, the other half of the gem being finished cabochon, or facets may be placed over the entire stone.

The important part of the technic of polishing facets on soft gems is the use of a very light touch, using lead or pewter laps, charged with *very little* polishing material. The polishing agent should be mixed thin, to a consistency no thicker than milk, and applied to the lap surface with the finger tips. If too much polishing agent appears on the lap, apply water in small amounts. The lap surface should also be cleaned at intervals, using a safety razor blade to scrape the surface while the lap is in motion. Only gentle pressure need be applied. The customary speeds are indicated, or the work may be kept nearer the center of the lap, which, in effect, is the same as reducing speed, since the surface foot per minute movement is greater toward the periphery of the lap. A very large table on a soft gem may give difficulties, and if a proper polish cannot be had on the metal lap, the felt or cloth buff will serve to finish this portion of the stone, as described under topaz.

DOPPING THE GEM

After the cabochon stone is shaped on the grinding wheels it will be found advisable to mount or "dop," on a small rounded wooden stick before proceeding further. Mounted in this fashion, the stone is much easier to handle in the sanding and polishing operations. Facet cut stones are also dopped in a similar manner, and small specimens are mounted even for the preliminary operation of grinding to shape and approximate size on the grinding wheels. Most facet cutting heads use metal dops which are countersunk at one end to permit the stone to fit down into a depression and thus enable the cement to get a better grip.

The dopping cement can be warmed over an alcohol flame and applied to the end of the dop, larger sticks being used for the larger stones. The stone to be mounted should be first warmed over a hot plate, or a piece of sheet metal fastened over an alcohol or bunsen flame. The gem to be mounted should be free of moisture and oil or kerosene. It should be heated gently to a temperature of about 150 degrees—not too hot to be touched by the finger. The molten dopping cement on the end of the dop is pressed down on the warm stone and with the fingers work the cement to position, using additional heat if indicated. Do not cook and burn the cement; it need be only at the melting point, which will vary with different cements.

Ordinary sized cabochon stones will generally adhere to the cements with little difficulty, if the proper technic be used. The larger the stone the more difficulty will be encountered; for, obviously, more pressure in polishing will be indicated. The stone can be more readily removed from the cement by first chilling in cold water, and perhaps slipping a knife blade under the stone, or the cement may be cut away. In washing a stone from one operation to the next, do not chill with cold water, for it may be released. If any cement adheres to the gem, wood alcohol will dissolve same. Dr. M. J. Grosbeck suggests the use of carbon tetrachloride (sold as non-inflammable cleaning fluid in any drug store), which is an excellent solvent for any of the cements.

TYPES OF CEMENTS

There are various dopping cements available in a stick form, or a cement may be made by melting equal parts of red sealing wax and flake shellac. The dopping cements sold by manufacturers are very satisfactory, and since they are inexpensive and can be used over and over, it is customary to purchase same ready to use. The several types of lapidary cement include: (1) *Stick shellac*, more convenient than the flake form for those who make their own cement or wish to give hardness to a cement by adding more shellac, which will raise the melting point as well. (2) *Sealing wax* is available in stick form and some lapidarists use it in this form as dopping cement. (3) *Chasers cement* will be found very effective in mounting large thin slabs on a wooden block, for convenience in the lapping, sanding and polishing operations. This cement holds well and is easy to remove from the specimen. (4) Special lapidary cements are available from the supply houses whose advertisements appear in the advertising section of this work.

For some special jobs a variation in the cement being used may prove advantageous. In general, a harder cement is indicated for the larger stones or specimens. Dopping is a simple operation and a little practice will soon enable you to quickly cement the stone to the dop in a satisfactory manner.

SPECIMEN CUTTING AND POLISHING

THE HORIZONTAL LAPS

The horizontal metal laps illustrated here are inexpensive and very useful, especially for finishing large flat surfaces on specimens. There are a number of excellent ready-made units of this type, pictured in the manufacturers' section of this work. These are sold at a reasonable cost. If you are handy with tools it is possible to construct your own horizontal running lap unit, and purchase the master iron laps, or have them cast to order at a foundry.

The horizontal running lap is inexpensive to operate, as only cutting grits and polishing powders are needed. The cutting and polishing of a large flat surface need not be limited to minerals of the gem class; often a compact specimen of a metallic sulphide can be greatly improved by polishing one of the flat surfaces. Often the polished surface will bring out interesting surface features not otherwise readily noted. Further, this equipment is invaluable in grinding thin sections for microscopical work. Grinding and polishing of opaque minerals and metals for examination under the microscope can also be carried on with the horizontal running lap. Hence, most well equipped gem cutting establishments have a unit of this type. Last, but not least, facet cutting is invariably done on the horizontal running lap.

For facet cutting the horizontal laps are generally run at low speeds—around 100 R.P.M.—for both cutting and polishing (eight to ten-inch lap). However, for roughing down a large specimen higher speeds will be found more effective and quicker. The higher speeds are also more effective in the final polishing operations.

Most horizontal running units are made with interchangeable pans and metal laps, so when passing from one grit to another it will not be necessary to clean the accessories. Simply wash the specimen free of grit and change the iron lap and the pan carrying the abrasive mixture. A separate lap is kept for polishing—generally a metal lap with a heavy layer of felt cemented on the surface will suffice for polishing the flat surface, or a wooden lap coated with felt can be used.

Three iron laps and separate pans are very convenient. For roughing down a large specimen to a flat surface, No. 100 grit (or coarser) can be used. This is followed with the iron lap and pan carrying No. 220 and then to No. 400 grit and finally the polishing. The silicon carbide grits are mixed with water and allowed to remain in their pans and used repeatedly.

The short vertical shaft shown in the illustration rests on a ball-bearing thrust with a bronze bearing at top. Some commercial units are fitted with ball or roller bearings throughout, which give better service and less noise in operation. The laps used in the grinding operations are generally made of ordinary cast iron ("grey" iron castings) and they need not be over one-half inch in thickness. They should be fitted to the vertical shaft by means of a tapered fit. This leaves the lap surface free of any projections and enables the easy change of laps without the use of tools. If the tapered fit is reasonably accurate the weight of the lap itself will be sufficient to eliminate any tendency to slip on the shaft.

Many home lapidarists operate units of this type with considerable satisfaction. A lap having a twelve-inch diameter will enable grinding and finishing a flat surface of large size, as without any projections on the lap surface the specimen can be worked across the entire face. Generally, speeds of around 700 R.P.M. are used, but this tends to throw the abrasive off the lap surface. The abrasive can be kept piled in front of the specimen by feeding by hand or by mechanical aids. Higher speeds cut faster, provided some provision is made to keep abrasive passing under the work. If the lap surface runs dry the specimen may suddenly "stick" and be jerked out of the hand.

The possibilities of the horizontal running lap are many and varied and additional uses will suggest themselves to the experienced operator. Much can be said in favor of this type of lapidary unit. For cabochon cutting it is nearly useless, although it is possible to do work of this kind by using metal laps with grooved and rounded surfaces in which the stones are worked to shape. Cabochon cutting can be done far more conveniently on the equipment intended for this work.

LARGE FLAT SURFACES

Cabinet size specimens with large flat polished surfaces can be finished in a number of ways, as referred to below. Polishing a large flat surface is obviously much slower than similar work on a curved surface, for a deep scratch is much more difficult to remove from a plane surface.

The first step in finishing a large flat surface is to reduce the specimen on one or more sides. This can be accomplished in a number of ways. Generally, sawing is the easiest and this can be done by either the "mud" or diamond charged saw, or for some materials the regular manufactured "cut-off" saws are quite suitable. If a reasonably flat surface is already present, coarse silicon carbide grits can be used on the horizontal running iron lap, or the side of a regular silicon carbide wheel can be used.

After a suitable flat surface has been obtained on the specimen the finer grits can be used on the horizontal running iron lap, starting with No. 120, then No. 320, and finishing with No. 400 or No. 500, when the specimen is ready for the polishing buff. In the use of horizontal running iron laps, it is advisable to have a separate lap for each grit, and thus avoid the risk of contaminating the fine grits with coarse material. The specimen should, of course, be well washed in running water before passing to a finer grit operation. This same principle holds true in *every* lapidary operation.

The final polishing can be done on a vertical running felt buff, or a felt can be applied to the surface of a horizontal lap and the polishing carried out in this manner. Special felts adaptable to the horizontal lap are described eslewhere in this work. The principal point to keep in mind is the fact that deep scratches cannot be removed by polishing, unless a very long time is spent at this operation. Hence it is advisable to remove them with the fine grit silicon carbide. Once the surface is properly prepared for polishing, the final operation will not take long. Most of the time will be spent in lapping down the surface to remove any deep scratches which may be left by the saw. A diamond saw will generally leave a better surface than an irregular running mud saw.

Horizontal running laps can be fitted with quite large cast iron laps, free of any projection in the center, to enable working a large specimen back and forth across the surface. "Grey iron" castings are generally used, and these should be kept wet with a thin mixture of abrasive grit and water. The specimen will tend to stick if the lap surface becomes dry. With a lap having a diameter of from ten to fifteen inches very large specimens can be ground and polished.

J. Lewis Renton of Portland, Oregon, suggests a variation of the above method. *The Renton technic* is given in outline below.

(1) Sawing is done in the usual manner with the diamond saw.

(2) The lapping is carried out on a ten-inch horizontal running iron lap, using first No. 220 grit, then No. 600. The speed of the lap is given as around

700 R.P.M. Mr. Renton uses a discarded commercial optical lens grinder as a horizontal lap, with excellent results. The ten-inch laps he uses were cast in a foundry to fit the tapered end of the vertical shaft.

(3) The surface is then buffed on a felt buff (vertical running), using in the order given (separate buffs) (a) "F". grit silicon carbide, (b) tripoli, (c) and tin oxide as the final polishing agent. The felt buffs are all 1x9 inches in size and are run fairly fast for buffing, namely, 850 R.P.M.

flat surfaces on cabinet specimens is given by Fred Roner, of Albany, Oregon. The *Roner technic* has been termed "The Dry Polishing of Large Flat Surfaces," and is given in outline below.

(1) The sawed surface is ground by two lapping operations—(a) No. 220 grit silicon carbide, followed by (b) No. "FF" grit. The lapping is done on horizontal running iron laps which are twelve inches in diameter and run at a speed of 600 R.P.M. The abrasive is mixed into a thin paste with water and

Adam Kahn demonstrating gem stone cutting. A new recreation introduced as part of the Chicago Park District art craft activities. Ridge Park shop, where instructions in gem cutting are given to the public.

It may seem out of order to pass from No. 600 grit on the iron lap, back to "F" grit silicon carbide, which is basically about No. 240 mesh. But with the buff surface much softer than the hard iron surface the effect is different. Experiments have indicated that No. 600 on the iron surface "cuts," while coarser grits used on a felt buff appear to remove scratches rapidly and save time. In place of the tripoli and tin oxide, one of the alumina polishing agents can be used with good effect.

DRY METHOD

Another method of finishing large

fed to the lap surface by the drip method, which consists simply of a short trough placed above the lap, and the thin mixture is fed slowly to the work from a container. This permits the use of both hands while working. Some operators apply the mixture from a pan surrounding the lap wheel. Finer grit than No. FF can be used in the (b) operation, and is advised by some workers, but the FF has been found satisfactory for most gem minerals.

(2) The sanding operation is carried out on what has been termed the "drum" type of sander, a wooden wheel twelve

inches in diameter, with a three-inch (or greater) peripheral face. A soft backing of carpet and felt is first attached to the periphery and over this padding a strip of No. 220 grit silicon carbide abrasive cloth is stretched tightly. The abrasive cloth is held in place by means of a thin wedge to fit in a slot cut in the wheel. Provision should be made to support this part of the wheel, otherwise when the wedge is driven into place the ends of the cloth will be pulled in too far and thus cause a "bump" in the wheel surface. By placing narrow strips of leather on both sides of the slot the cloth will be supported and keep the working surface true at this point. The slight depression of the wedge will not affect the sanding of a large surface.

The vertical running drum sander of the diameter stated here is run at 1,000 R.P.M. This wheel is used until all scratches left by the previous lapping operations are removed. A new sanding cloth tends to produce a surface too rough for the following and final polishing. Hence it may be necessary to "retouch" the work on a worn cloth. Some lapidarists use two sanding wheels at all times, regardless of what type of sander is used, one carrying a well-worn cloth and the other a less worn or new one. Be sure that all lap marks and scratches are removed, otherwise the final polisher will fail to "take hold."

The advantages of the "drum" sander are principally in speeding up the work, economy of abrasive cloth and a better final finish. The drum sander with a soft backing leaves an apparently flat surface with slightly rounded edges, which appears to add greater "life" and gloss to the specimen. It is also easy to sand off a scratch quickly without cutting down the entire surface, as is necessary with the type of sander where the work is done on the side of the wheel. Furthermore, if a scratch is produced by the drum sander it is only a short and insignificant one. A disk sander, on the other hand, tends to produce longer and deeper scratches, since more surface is in contact with the specimen.

FINAL POLISH—DRY

The final polishing operation is carried out on a wheel running on the end of a light grinding head (arbor). The polishing wheel is of the disk type (like a sanding disk), vertical running with the working surface turned true with a slightly convex surface, from the center to the periphery. The wheel should be thick enough to encase the [illegible] holding the wheel to the end of the shaft, thus leaving the entire surface free of any obstructions.

Over the surface of the wooden wheel is stretched a 1/4-inch thickness of cloth or felt. Next, select a *well-worn* sheet of silicon carbide cloth, one that is no longer useful for regular sanding, and stretch this tightly over the side of the wheel and fasten on permanently. Tin oxide (or alumina powder) is applied dry to the surface of this worn cloth by means of a putty or caseknife, the object being to run on a thin coating of the polishing agent which will not be thrown off when the wheel is in motion. It is this very fine "dust" coating of polishing powder that does the work, and it should not be touched or scraped with a sharp edge of stone. It is a delicate surface when in condition and should be protected to obtain best results. Some lapidarists prefer the use of *levigated alumina* in place of the tin oxide. This appears to be a matter of choice.

The work is applied to this charged surface with a slight motion to prevent wheel marks from appearing. Polish one-half of the large surface at a time, holding the work so that the edges do not cut into the polishing cloth. Some heat will be generated, so it is advisable to rotate the specimen as it becomes warm to permit even heating and prevent possible fracture. If the surface feels gritty and fails to polish flat surfaces, a number of cabochons can be worked, which will aid in further wearing of the cloth. A polishing cloth properly prepared should last indefinitely if used carefully. Each application of polishing powder should take care of two or three average sized specimens, and the surplus powder that drops off the wheel can be used again. One teaspoonful of polishing powder will finish at least 400 square inches of material the hardness of agate. A small suction fan can be used to eliminate dust if desired.

The advantages of this process over the "wet" polishing methods are that porous stones are not filled with polishing powder or undercut. The progress of the work can be watched to any degree of final finish, and scratches are reduced or do not occur with careful work. The beauty of the finish is also enhanced by the slight curve that forms on an otherwise flat surface. The reflection of light from a very slightly curved surface seems to lend the illusion of depth and high gloss.

The final polishing operation as given above takes a little more time compared to the "wet" methods, but the final results are better, and, after all, the amateur home lapidarist is not especially concerned with time. On the other hand, the time saved with the drum sander will offset this to some extent. It takes time and patience to properly work down the polisher surface to a perfect condition and the beginner should not be discouraged with his first few attempts. During the long winter evenings make it a rule to finish one large specimen each evening. You will be surprised how soon you will have an attractive cabinet of beautiful and valuable polished pieces.

CONSTRUCTING FELT WHEEL

The amateur lapidarist can construct inexpensive felt polishing wheels by the following method.

Make a disk of wood with a hole in center to fit the arbor on polishing head. This disk can be made of a diameter and peripheral thickness to suit the need of the worker. If desired the disk can be cut and made true by any woodworker at a small charge.

The circumference of the disk is coated with *Duco* cement or waterproof glue and a strip of felt about ¼ inch thick is cemented around the circumference. Stretch the felt fairly tight and use brads to hold until the cement dries, when they are then removed prior to using the wheel. The sides of the wooden disk can also be covered with felt, to permit the use of the large flat side surface.

When the cement has set a chisel can be used to true up the surface of the felt, and the edges trimmed. Use a sharp chisel, while the wheel is in motion, holding the tool carefully and steady on a rigid rest. Care should be used to place the lap joint in the proper direction, so when the wheel is in operation the union will not be torn. The above method offers the advantage in that the gem cutter can have available numerous felt buffs for use with various polishing agents and yet not make a large investment. Naturally the life of a felt buff of this type is limited, but they are well suited for other than commercial shops. A proper type of fairly hard felt is available in sheets from supply houses, or the felt used in padding saddles can be used.

Sheets of felt can also be used on the horizontal lap for the polishing of large flat surfaces. A proper size wooden disk is made to fit the master iron lap or placed directly on the end of the vertical shaft. The wooden or metal disk is then covered with a sheet of felt, using the same cement as indicated above. Large size, 15 to 20 inch polishing felts can be made in this manner, which will operate satisfactorily in polishing.

CUTTING AND POLISHING TRANSPARENCIES

Thin sections of transparent or translucent gem minerals can often be conveniently displayed as "transparencies," using daylight or artificial light for illumination.

A number of methods will suggest themselves, a few will be detailed here. Large slabs of agate can be very effectively displayed in this manner. The sections need not be cut very thin, merely sufficiently thin to permit the passage of light through the specimen. This will be dependent largely upon the material itself and the intensity of the illumination. Some specimens show up well if cut ¼ inch in thickness, others must be sawed or lapped down further.

A rough irregular shaped specimen can be displayed with the edges in the rough form and not detract from the beauty of the pattern. Generally the diamond saw is used to saw the section to proper thickness. The horizontal lap or the side of the grinding wheel will serve to further reduce the thickness and remove any deep scratches left by the saw. Since the specimens are often mounted between glass, a high polish is not essential. Or as an alternative to polishing, the flat surfaces can be given a light sanding and then given a coating (both sides) of Dake Varnish. Since the transparencies mounted behind or between glass are not handled, the varnish method gives good results and only very close observation will indicate the specimens have not been polished. Moreover, polishing a large flat section on both sides entails considerable labor; the varnish will eliminate much of this labor.

PICTURE FRAME METHOD

.. One popular method of displaying small thin agates, and similar gems, is mounting in a frame used for photographs. Various size frames can be utilized according to the fancy of the individual.

The specimens are placed on a piece of light or black colored cardboard, the same size as the glass in the frame. A mark is then made around the outline of the specimens, and holes are cut to correspond. The specimens are then placed in the spaces and a glass placed behind. The cut stones or thin specimens are now mounted between two pieces of glass. The light passes only through the specimens, thus making them stand out in contrast. The frame can be viewed by hanging in the window, or held toward any light. Small size frames of this kind make admirable desk ornaments.

ILLUMINATED FRAMES

The above method can be used in the same manner, except that a boxed in illumination is used as a source of light. Discarded commercial illuminating advertising signs can be effectively utilized. Generally signs of this kind are made of metal, portable, wired for electric globes, and fitted with a glass on the front. The advertising sign on the front can be removed by scraping the paint from the glass. A similar size section of glass is cut to fit the back of the cardboard same as is used in the picture frame arrangement. This method offers numerous attractive and artistic possibilities. A frame of this kind measuring 12 by 24 inches can be filled with a very colorful array of cut stones and irregularly shaped specimens. At least an inch of dark space should be left around each specimen, packing in too many is not effective. Illuminated frames of this kind could be used to good advantage in commercial display windows, at night, intermittent illumination attracts attention.

GROUND GLASS ILLUMINATION

A slanting shelf of ground glass can also be used to display transparencies. Special lights are placed behind the ground glass to give a pleasing diffused light. Cardboard is not needed to eliminate any excess light; the thin specimens are placed directly on the slanting glass shelves. Mr. A. N. Goddard, of Detroit, Michigan, uses this method with very pleasing results. Visitors viewing the Goddard collection are placed in comfortable chairs facing the special cabinet. The lights in the room are extinguished, and, one by one, the various parts of the cabinet are illuminated from a central control. The Goddard illuminated cabinet is built about a large fireplace, and the final surprise comes to the visitor when the lower portion of the cabinet is slid aside, exposing the original fireplace opening, where a magnificent collection of fluorescent minerals serves as a fitting close to the array of beautiful colors.

MOUNTED TRANSPARENCIES

William B. Pitts, noted "amateur" lapidarist of Sunnyvale, California, has suggested a means of mounting transparencies which holds wide possibilities. By this method a number of semi-precious gem minerals can be arranged to be viewed as transparencies. The thin section specimens c also be cemented on lantern slides a thrown upon the screen.

Chiastolite crystals are next to imposs to polish in a satisfactory manner. Pitts, in experimenting with this mate employs the following technic of mount Obviously the same method can be used a number of similar materials.

The delicate patterns seen on cross tions of chiastolite are due to inclusions carbon, and no two are exactly alike. T mounted frames of glass can be viewed holding toward any light, projected on screen, or used in an illuminated frame. T low priced projectors fitted with *Polaro* can be used to project various thin sectio on the screen under ordinary light or pol ized light. Some gem minerals give remar ably beautiful interference colors when pr jected with polarized light. The recent in troduction of the new polarizing substanc *Polaroid*, offers some fascinating possibi ties in the way of entertaining and educa tional programs.

SAWING CRYSTALS

The crystals of chiastolite are first c across the face, by the diamond or mud saw to a thickness of about 1 mm. (1 mm.=1/2 inch) or thicker. The sections are the ground by hand by holding on the side o the grinding wheels or the horizontal lap until light will pass through the section. Th thickness of the section will be depende upon the opacity of the material. From on to three mm. will be the average. The specimen is then made smooth on both sides by lapping on the iron lap with No. 500 or No 600 silicon carbide grit. No attempt is made to polish as this is not needed. If a horizontal lap is not available, the sections can easily be worked down by hand labor, using a plate glass slab and a mixture of water and grit. Hand labor is not tedious unless the sections are very thick to begin with.

MOUNTING ON GLASS

The thin sections of chiastolite (or other material) are then cemented to a suitable size section of ordinary window glass. Ordinary varnish can be used, but canada balsam will be found much more effective. The canada balsam is the liquid kind, the same as is used in mounting thin microscopical sections of rock or minerals. A drop of canada balsam is placed under each small section and the excess pressed out. The glass slab with the arranged and cemented specimens is then "cooked" to dry the cement. A temperature of nearly boiling is necessary to properly dry the balsam. A low temperature hot plate or oven will suffice. Or the plate can be left under a strong electric light and the heat will dry the balsam in a few hours. If the balsam is not cooked enough the specimens will tend to slide about on the glass; if this happens, further heating is indicated.

GRINDING AND BACKING

If some of the specimens appear too thick further grinding can be done on the cemented specimens. The entire face of the slab can be ground on the horizontal lap. If the edges of the glass mount become "frosted" from the abrasive, no harm will be done. Grind until light passes through the thick specimens.

An opaque backing of some kind must now be placed between the thin sections of chiastolite or other material. William Pitts advises the use of a thin layer of *Handeewood*, a plastic similar to the familiar plastic wood. A thin layer of this substance is spread over the specimens and the excess squeezed out by pressing down on a glass plate. Any surplus material covering the face of a specimen can be scraped off with a knife. About two hours will be needed for the setting of the *Handeewood*, when the edges and sides can be trimmed with a knife.

The entire surface of the backing and specimens can be varnished over with ordinary or Dake varnish. To better protect the specimens a glass plate can be cemented over the backing, using liquid canada balsam, and again "cooking" the plate.

SAWING LARGE SPECIMENS

Large specimens can be sectioned by various methods, a number of which are detailed below. The circular metal disk has its limitations as to size for obvious reasons. In general, hand-charged metal diamond saws are generally not made over about 24 inches in diameter, and with the retaining flange in position this limits the disk to sections about ten inches in diameter.

LARGE MUD SAWS

Mud saws of quite large diameter can be used, provided they are operated at low speeds, and not too much pressure applied. At various places in Arizona and elsewhere large sections of petrified woods are sectioned by the mud saw. Blades up to 50 and 60 inches in diameter are in use and appear to give reasonably good service, provided they are used properly. A large disk 50 inches need not be of a gauge heavier than two or three times the thickness used for a twelve-inch blade.

The chief disadvantage of mud saw blades over thirty inches in diameter, is the tendency to travel sideways, and, of course, considerable power is required to drag the disk through a large section. The side travel can be largely eliminated by the application of the proper amount of pressure of the work against the disk.

One cutting establishment in Arizona does the sectioning of large petrified logs in an open-air shop. Here a battery of a dozen or more large blades is connected to a six-cylinder automobile engine as a power plant. The blades are mounted on each end of an old automobile differential, housing and all being set up on supports, and the disks attached to each axle, except where the axle operates the adjoining unit. Power is then supplied through the drive shaft attached to the differential housing. The saws are operated in a position close to the ground, which enables the "mud" mixture being placed in a pit dug in the ground. Some of the logs sectioned weigh hundreds of pounds and present a problem to support while sawing. This is cleverly solved by lashing the specimen with cables or a chain to a heavy timber. The timber rests on a fulcrum like a balancing beam, and by placing weights in a box at the opposite end of the timber the specimen can be balanced in such a manner that the right amount of pressure will be applied. The work is done on top of the saw. Most of the units are made from old automobile "junk" parts, and include the transmission. This enables obtaining three different speeds, by shifting gears just like in an auto.

The large mud saws described above appear to give good satisfaction. The skilled workmen are enabled to produce reasonably even cuts with little difficulty. Sections from twenty to twenty-five inches in diameter may require several days to complete, but the operating cost is low. Owing to the low speeds at which the saws are operated, they seldom develop "flats," and if these do appear they are not serious and are given no attention. High speeds would, of course, cause considerable bumping and vibration and jam and bend the blade. The usual No. 120 grit silicon carbide is used as the cutting abrasive.

BAND SAWING LARGE SPECIMENS

For specimens over 20 to 30 inches in diameter some means for sectioning other than the circular disk is indicated. The band saw as is used in the woodworking industry can be adapted to handle large sections of very hard minerals, and saws of this kind are in operation at institutions, including the United States National Museum and Harvard University.

The equipment used is identical in general arrangement to woodworking band saws, except that changes made be indicated in order to give clearance to accommodate a large section. Some large woodworking saws have 36 inches or more clearance between the two driving wheels. One of the advantages of this equipment is that sections of indefinite length and width can be handled. The diameter of only one direction is to be considered to enable the work to pass between the driving wheels.

Obviously a number of changes are necessary before a woodworking band saw can be utilized for sawing hard mineral or rock sections. The steel blade with teeth can not be used for sectioning minerals. Special saw blades without teeth are used. These can be obtained direct from the manufacturer and are merely a thin band of semi-steel. The regular blade used in wood sawing is first made as a thin band of "mild" steel, the teeth are then cut and the saw further hardened. The blade as it appears prior to the cutting of the teeth is the type of band suitable for lapidary purposes.

Arrangements must also be made to properly shield the saw to prevent splashing of the abrasive and to protect the operator in the event of breakage of the blade. Woodworking bandsaws come equipped with a heavy base to hold the work, and this can be fitted with a sliding carriage to feed the work to the saw. Counterweights on a pulley arrangement will give the proper tension of the work against the saw.

One of the advantages of the band saw is the fact that the abrasive is fed it at the upper part of the cut and the saw runs downward through the work. By this means a constant stream of abrasive is fed directly to the cutting point. Moreover, the cutting blade is quite thin and does not present the large friction surface of a large mud sawing disk. The bandsaw can be run at quite high speeds and it is surprising how long a proper blade will give service and still show little wear.

The thin blade of the band saw would of course tend to travel in a lateral direction if improper pressure is applied. Forcing the work against the blade will only cause side travel and will not hasten cutting. Bandsaws come fitted with steel rollers to hold the saw in position, or grooves cut on the fly wheels will help. The No. 120 silicon carbide "mud" mixture can be collected in a reservoir below the work and used over and over again; fresh abrasive, however, operates faster. Some experience is necessary to use this type of saw properly and it is recommended only for special purposes.

The manner in which the band saw is used at the United States National Museum is given below. Acknowledgment is made to B. O. Reberholt, Preparator in the Department of Geology, for this information.

"To the best of our knowledge, band saws are not manufactured especially for cutting minerals. The equipment in use at the Museum is one which was originally constructed for wood sawing, and adapted to cut minerals. The wheels of the band saw are 36 inches in diameter, and have a speed of 100 R. P. M.

"There is a solid iron base between the wheels, with a sliding base upon it to which the minerals to be cut are clamped. The sliding base or carriage is constructed so as to move the specimen against the cutting band. Silicon carbide, number 100 grit, is used as the cutting abrasive. This is mixed with water and fed to the cutting blade by a tin and clay trough arrangement. The abrasive mixture can then be carried to the point of cutting by a small drip stream of water.

"The band saw blade (blank) is of course without teeth. It is one and one-fourth inches wide, of suitable length to fit over the wheels, and of 18 B. S. gauge. Extensive shielding is not necessary, other than to protect the operator in case of breakage of the blade. Proper band saw blades may be purchased from manufacturers, including the Oliver Machinery Company, Grand Rapids, Michigan."

GANG SAWS

Steel blades of the hack saw type can be used to section large specimens, and these can be used separately or multiple as a "gang" saw. Prior to the introduction of the modern circular diamond saw, the early lapidarists used a steel blade charged with diamond dust or grit to section hard minerals. This device operates in the same manner as a hack saw would be used. Power can be applied by an electric motor in place of tedious hand effort.

The hack saw method can be used as a "mud" saw, but it holds no advantages over the circular running types. A number of hack saw blades can be arranged to operate together as a gang saw and section one large specimen into several or more flat slabs. These methods are not in common use at present time. The gang saws are troublesome in many ways; a fragment of hard mineral may become lodged between the blade and the work, resulting in wrecking the equipment or the work.

WIRE SAWS

An endless wire functions very well in sawing large masses of mineral where *soft* substances are being handled. The wire cutting method is in wide use in the marble industry, where a flexible cable several hundred feet in length may be used to quarry large masses of marble. Ordinary silica sand makes an excellent abrasive to cut marble and similar soft minerals. The wire saw is not satisfactory for cutting hard minerals.

CUT-OFF WHEELS

Silicon carbide cut-off wheels or saws can be used for sectioning minerals. Generally saws of this type are resinoid or rubber banded. They function best with minerals having a hardness of seven or less. Cut-off wheels made of silicon carbide find wide use in sectioning rocks and minerals for microscopic work, for here we are working with very small fragments and a thin cutting blade can be used.

Cut-off wheels are run at surface speeds considerably higher than the "mud" or hand charged diamond saws. Water or some lubricant should be used if large sections are to be cut. The saw should be well shielded in case of breakage. In working small sections of some gem materials the cut-off saws are useful in the "resawing" operations.

CALCULATING SPEEDS

As an aid to those installing lapidary equipment, various rules for calculating wheel and shaft speeds are given below.

(1) To find the Surface Speed of a wheel in feet per minute: Rule—Multiply the circumference in feet by the wheel revolutions per minute. Silicon carbide grinding wheels used in lapidary work give best results when operated at a surface (peripheral) speed of 5,500 feet per minute. Thus for a 12 inch wheel the revolutions per minute (R.P.M.) speed would be 1,751, but it follows that a small wheel would be operated at a greater R.P.M. speed to give the required surface foot speed. Hence a six inch wheel should be run at approximately 3,500 R.P.M. for best results.

(2) To find the number of revolutions of wheel spindle, surface speed and diameter of wheel being given: Rule—Multiply surface speed in feet per minute, by 12, and divide the product to 3.14 times the diameter of wheel in inches.

(3) To find proper speed of countershaft (line shaft), proposed speed of grinding arbor being given: Rule—Multiply the number of revolutions per minute of the arbor by the diameter of its pulley, and divide the product by the diameter of the driving pulley on the line shaft.

(4) To find the diameter of pulley to drive arbor, speed of line shaft being given: Rule—Multiply the number of R.P.M. of the arbor by the diameter of its pulley, and divide the product by the number of R.P.M. of lineshaft.

FACET CUTTING GEM STONES

Can the amateur do satisfactory work in cutting gems into facet styles? The answer is "Yes"—if the aspirant has a fair degree of mechanical ability, a knowledge of gem minerals and the patience to practice the art.

The novice should not, however, attempt fast cutting until such time as he has mastered the art of cabochon cutting. Facet cutting as a whole requires no marked degree of "secret skill." However, it is admittedly more difficult than cabochon work. The actual mechanics of facet cutting are relatively simple compared to the problem of properly orienting and cutting a gem to obtain the best color, brilliance and appearance, and this can be learned only by experience. For instance, the experienced and highly skilled commercial facet cutter will examine a rough pebble of blue sapphire and determine if a choice color area is present. He will then orient the color area (generally near the culet) in such a manner as to make the entire gem appear of a good color. The less experienced and skilled facet cutter would perhaps entirely overlook possibilities of this kind.

For centuries the skilled facet cutter has fashioned exquisite gem stones with crude equipment and often with no real knowledge of the optical properties of the stone. But with long years of experience and doubtless numerous "experiments," the best angles and orientation were learned. Even today some well qualified facet cutters are using the same type of equipment and technic that has been in use for many years. Since the technic of facet cutting has long been looked upon as a "trade secret," it is not surprising that the libraries are practically devoid of data of this kind. A few antiquated and very incomplete works are available, but it is only in recent years that modern technical methods have appeared in the printed form. Equipment and technic for facet cutting suitable for the "amateur" as well as the professional has been studied in the laboratory of THE MINERALOGIST magazine. This data and the findings of other workers have appeared in these pages during the past five years. New abrasives, polishing agents and equipment have been tried and tested in the laboratory and the findings made available to everyone. This is done with the idea in mind of rendering the technic more simple, speeding up the work, improving the finished product and creating a wide public interest in the possibilities of gem stone cutting as a hobby.

In facet cutting due regard must be given to the arrangement of the many small flat surfaces (facets) on the gem. Not only must they be placed in a symmetrical manner, but they must be inclined at the correct angles in relation to the table. This is the secret of the brilliance or "life" of some gem stones. Gem stones in the rough are generally unattractive and would perhaps be discarded in many instances by the layman. A diamond or a colorless zircon in the rough state would doubtless be passed by, by any but the experienced. Transparency, reflection, luster, color and brilliance become plainly evident only after the rough fragments have passed through the hands of the skilled lapidarist.

Properly fashioning a facet cut gem includes orientation of the material in relation to its optical properties, removing flaws and blemishes, areas of improper color, proper proportions to the various parts of the gem, proper inclination of the facets, and a final finish free of visible scratches.

METHODS USED

There are several basic methods used in the cutting of facets on gem stones. These devices can be grouped in two general classes—first, the method where the gem is cemented to the "stick" or dop and then held by hand against an upright post standing at right angles to the surface of the lap. This method is the oldest of all and has been in use for centuries. The second method consists of a mechanical device to hold the dop, to give various angles, and permit the gem to be rotated by mechanical means in placing the facets in proper position. This method is recommended for the "amateur."

With the older method where the dop is held by hand, the angles of the various rows of facets are obtained by merely placing the end of the dop in the proper notch on the upright, which is termed jamb peg or gem peg. To do good work with this method it is obvious that a certain degree of skill is called for, which can be acquired with practice and experience. Most of the native cutters of the Orient use a device of this kind and many commercial cutters use the method. The jamb peg offers a distinct advantage over mechanical methods in that the gem can be rotated as much or as little as required. It is very useful for calibre cutting or for recutting a portion of a damaged gem stone.

Mechanical facet cutting device, enables obtaining proper angles and correct position and division of facets on gem stones. Facets are cut and polished on horizontal running lap wheels.

The mechanical facet cutting devices illustrated here not only hold the gem at the proper angle, but enable the worker to properly space the facets on the stone. Without an aid of this kind the novice would find the task a very difficult one. A notched wheel divided into thirty-two spaces enables the operator to place the facets accurately and in proper proportion. Thus where there are four or eight or sixteen facets in a row, the same can be readily placed by simply setting the device. This leaves the cutter free to watch only the actual area being cut. Moreover, with the swinging arm and hinge joint the gem can be swung across the face of the lap wheel or can be raised to examine the facet and yet not lose position. A broken facet on a gem can be recut and polished by the use of the mechanical cutter, but some difficulty may be encountered in properly centering the broken area. This, however, is rather a minor point, as a gem stone "patched" or repaired retains but little (stones not cut for color) of its original brilliancy, and may better be completely recut, thus reducing its size by retaining the original beauty.

The horizontal running lap is in almost universal commercial use and is recommended for the beginner. In polishing facets on a gem stone, much depends upon keeping the polishing agent on the lap at the proper consistency. This can be done much more readily on the horizontal lap. Some workers use a vertical running lap, but there are many disadvantages to this method. Another disadvantage to the vertical lap is the possibility of side play from thrust at the bearings.

SPEED OF LAP WHEEL

The lap wheel unit in itself is an important factor in good workmanship. It should be built to run true on its bearings, free of side play, and variable speeds should be available. Speed is not an important factor in the cutting of the facets, but in polishing, high speeds are not indicated. An eight-inch lap revolving at an approximate speed of 100 R.P.M. is recommended for the polishing of practically every gem stone other than diamond and sapphire. Diamond cutting is not within the domain of the amateur, and none of this work is applicable to this gem. The several horizontal running lap wheels illustrated here are suitable for facet cutting.

The horizontal running lap recommended for facet cutting is the type where the solid cast and expensive laps are eliminated. A master solid cast iron lap, one inch thick and made true on a lathe, is tapped in the center to accommodate a threaded bolt with a wing nut. This is the only solid cast lap required. All additional laps for both cuttin grinding and polishing are available thin disks. Sheet metal supply hous can furnish laps of this kind, accurate cut with hole in center and rolled fl These are available in every metal fro aluminum to zinc and in many alloy including pewter and bronze. The ac vantage of these sheet metal laps res ing on the master iron lap, are man Where a special solid cast lap of tin c copper may cost $10.00 or more a met disk lap can be purchased easily for onl

Facet cutting device, showing dop arr raised to examine progress of work. Descrip tion of device given in text.

a nominal sum. Further, *both* sides o the sheet metal laps are available fo use. When the surface of the lap be comes badly scarified it can be dis carded and a new disk provided at a very small cost. In short, a new disk la can be purchased at a cost less than th machining of the surface of a heav cast lap. Finally, since most facet cut ters use a number of different abrasive it will be possible to keep a number o laps, reserving each one for some spe cial abrasive or some special gem stone For instance, a special lap can be kep for polishing quartz gems, and not usec for harder stones and thus avoid the possibility of contaminating the surface with fragments of some harder gem mineral which would cause scratching of the quartz.

KINDS OF LAPS

Most facet cutters use at least several different laps in cutting and polishing facets, and these generally include iron, copper, bronze, tin and pewter. The copper lap will be found satisfactory for cutting the facets by the use of silicon carbide or *Norbide,* some workers prefer bronze or lead disks. For polishing, the tin and pewter disks appear to be in almost universal use. The iron lap is used to both cut and polish sapphire. A soft grey iron casting will be found best. Very soft laps like felt and similar materials are not suitable for facet polishing, since they tend to round the corners and angles where the facets meet. Sharp lines where the facets join are the marks of good workmanship.

A low removable splash pan is built around the lap wheel to catch any abrasive thrown off. However, this will not be noticeable since the low speed of 100 R.P.M. recommended for both cutting and polishing will throw very little abrasive or polishing powder.

FACET CUTTING DEVICE

The mechanical facet cutting devices operate on similar principles, in that they aid in proper placing of the facets at the correct angles. The device illustrated here shows the working position with the stone resting on the lap, and with the swinging arm raised for examining the progress of the work. With a unit of this kind it will be possible for the beginner to do creditable work with a minimum of practice and experience.

A worm gear on the inside of the supporting column permits the free raising or lowering of the dop arm to the desired angle. A protractor is placed on the dop arm holder and a hair-line indicator attached to the dop arm gives correct direct readings of angles at all times. The dop arm has a gear arrangement at its upper end. It can be revolved by a simple turn of the wrist. The gear on the upper end of the dop arm has thirty-two notches or teeth, while a spring steel locking device holds the d arm at any desired position.

FACET NAMES

Facets on gem stones are known name, and so you will understand t order of cutting, let us become fami with these names, using as an exam the "brilliant" style of cut, the man in which most diamonds are fashion

The gem is divided into two portio the upper the *crown* and the lower t *pavilion* (or bottom), the *girdle* bei the thick portion or greatest circumf ence and divides the stone. Table is t largest flat surface at the summit of t crown.

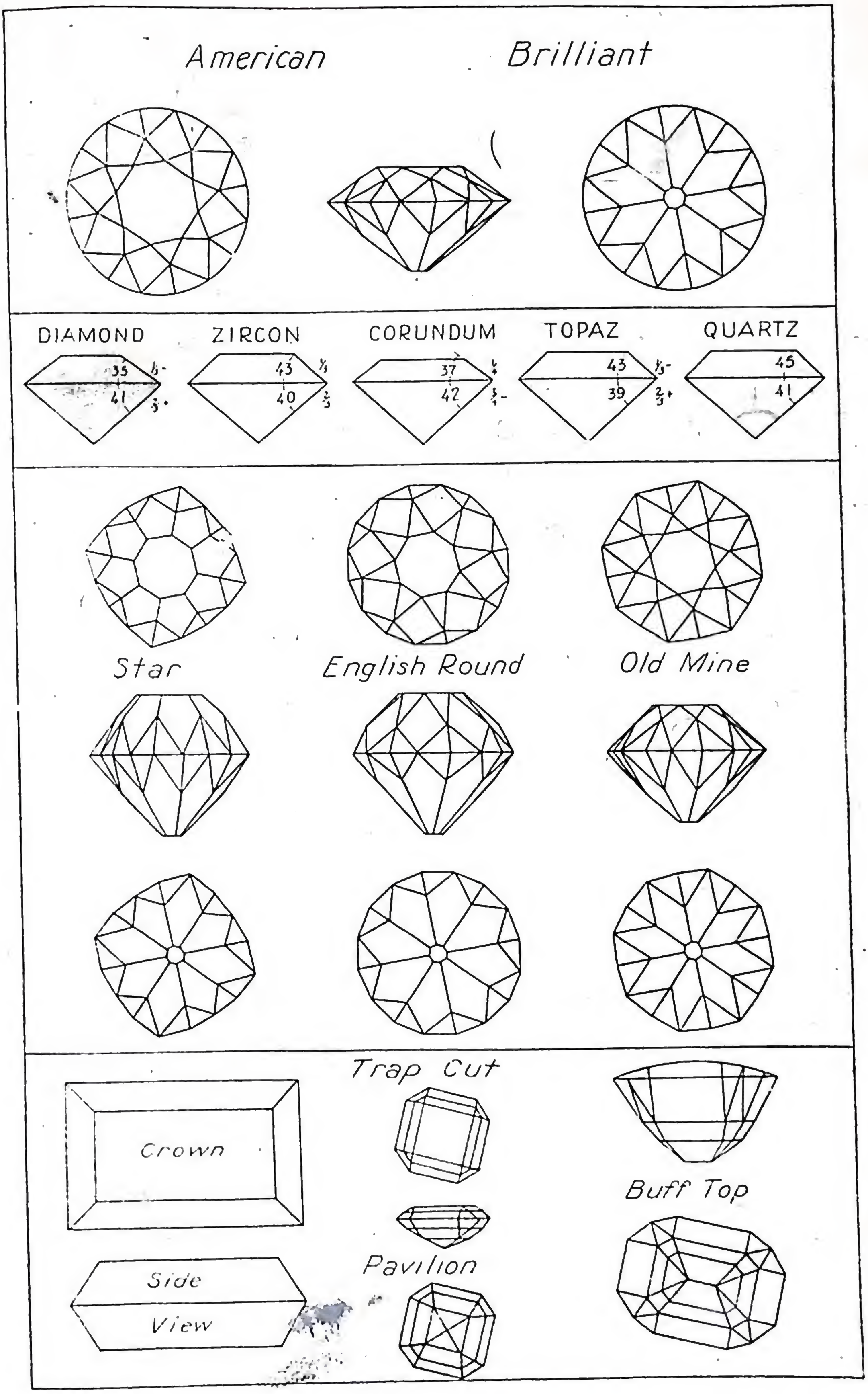
The crown of the stone is usually c with thirty-three facets in the standa brilliant cut, divided as follows: O table, eight table facets, eight ma facets and sixteen girdle facets.

The pavilion carries twenty-four fa ets, divided as follows: Sixteen gird pavilion facets and eight main pavilio facets. Thus the normal standard br liant carries a total of fifty-seven face There are many variations of this sty it being possible to add more facets t either the crown or the pavilion portio

Most of the older style cuts fro which the modern standard brillia was developed carry a less number o facets. However, there are variou freak cuts which may present hundred of facets, placed on the stones with lit tle or no mathematical order, the fanc of the cutter prevailing. The *step* o *trap* cut are usually square or rectangu lar forms and carry a varying number o facets, but generally less than the stand ard brilliant.

CUTTING THE FACETS

The first step in cutting a facet ston is the determination of the position o the table in relation to the crystal axis o the gem material at hand. Due consider ation should also be given to the pres ence of areas of color, flaws, imperfec tions and similar factors. The fragmen of material or the crystal is the roughed out to shape on the silicon car bide grinding wheels. The reader i here referred to the data under "Sys tem for Facet Cutting," appearing i these pages.


American Brilliant
DIAMOND
35
41
ZIRCON
43
40
CORUNDUM
37
42
TOPAZ
43
39
QUARTZ
45
41
Star
English Round
Old Mine
Trap Cut
Crown
Side View
Pavilion
Buff Top

In the roughing out operation enough excess material should be left to allow for the part removed when the facets are cut. The girdle should also be left slightly thick. This will be better determined after a little practice.

Silicon carbide will cut the facets rapidly on all gem stones having a hardness less than nine. Sapphire and similar hard gems can be cut to best advantage by the use of *Norbide*, which will leave clean, sharp angles between the facets, while silicon carbide tends to round the angles as well as the surface of the facet. Some gem cutters use *Norbide* for all gems having a hardness greater than seven.

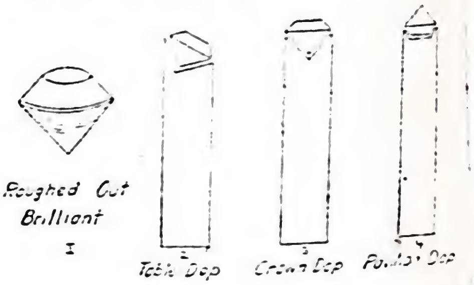
Various grit sizes can be used in cutting the facets on a gem. As a rule the skilled commercial worker uses the coarser grits from No. 280 to No. 320. However, the novice will find it a distinct advantage to work with fine grits only, to enable better control of the amount of cutting. Often a very small facet will require only a few single light touches to reduce it to the proper size. Hence the degree of cutting can be better controlled by the use of fine grits No. 400 or No. 500. Moreover, using fine grits will leave a surface with no deep scratches; hence less time will be consumed in the polishing operations. Examine the work frequently and note the extent of the cut. Otherwise the facet may be greatly overcut, which might mean reshaping the entire gem. By the aid of the mechanical facet cutting devices no difficulty should be encountered in properly placing and cutting the facets. The beginner's difficulty will be mainly in properly shaping the gem and in the final polishing operations.

GEM MATERIALS DIFFER

The mechanical part of facet cutting is really quite simple, and were it not for the fact that each gem material offers a different problem, we would be inclined to state the beginner could master the art in a very short time. But unfortunately there is much to learn before you will be successful with all types of gems. You should have a fair knowledge of crystallography, as well as the optics of light, referred to in a special chapter.

There are numerous styles in which facets may be cut on gem stones, the *trap* or *step* cut being next in popularity to the brilliant cut. The trap cut is frequently applied to colored gems, when the stone is cut to bring out the best color, while the brilliant is applied most often to colorless or very pale stones. The trap cut is a more simple design and carries a smaller number of facets. (See illustrations.)

Bronze, copper or iron laps are generally used for the cutting of the facets. A large amount of abrasive need not be used, for cutting will proceed fast enough with the lap surface merely made moist with a mixture of water



(1) Brilliant roughed out on grinding wheels prior to mounting on dop. (2) Stones mounted at angle to permit cutting and polishing of table. (3) Stone mounted to expose crown portion in cutting and polishing crown facets. (4) Reversed position of gem for cutting and polishing pavilion facets. Various size dops, with countersunk slots accommodate all gems.

and the cutting grits. The speed of cutting can be controlled by holding the work toward the center of the lap, where the speed is less, and cutting will be slower. Most workers apply the abrasive mixture to the lap wheel with a small soft brush, spreading the same with the fingers of one hand. In cutting the facets do not completely join the facets, as the polishing agent acts as a mild abrasive as well as polishing, and allowance should be made for this further reduction. There are often hard areas in a gem, where cutting will proceed slightly slower. This is especially noted in some sapphires, where several times as long may be required to cut or polish certain facets. The technic of cutting facets is essentially the same for all gems, the only variation being in the rapidity of cutting. The real problem is the polishing.

POLISHING THE GEM

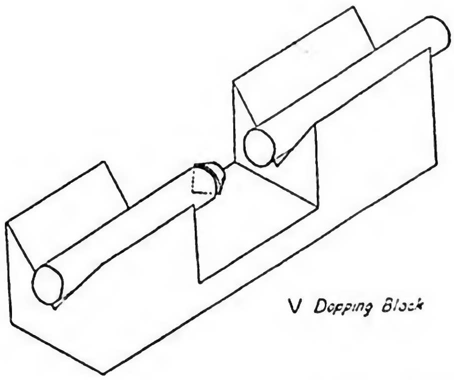
Like in all other types of gem stone cutting, care must be exercised to avoid carrying grits to the polishing tool. Hence, make certain the gem, dop and cement is washed free of all grits prior to polishing.

It is difficult to explain in detail the technic of polishing a facet gem, for the operator must develop a sense of touch that can only be acquired from practice and experience. No two gem minerals will polish in exactly the same manner. In some instances heavy pressure is applied, while in others a very light touch will suffice. The ear of the facet is also to be considered; the larger the facet the more difficult the polishing. Your experience in cabochon cutting indicated that even a slightly rounded surface will polish much more readily than a flat surface, and this same principle is applicable to facets.

The first and most important detail to master is the application of water and polishing agent to the lap surface. Too little water will allow the lap to run dry; the polishing agent will pile up under the stone and may cause scratching. It is customary to start with plenty of thin mix of polishing agent and water, working first toward the periphery of the wheel. In the final stages of polishing the work is carried toward the center of the lap, less water is used and a lighter touch given. Working from the periphery toward the center has its advantages in that in the event small fragments of gem material adhere to the lap they will tend to work outward and thus not cause scratching near the final polishing stages.

The lap wheel should be frequently cleaned and fresh polish applied. While polishing, use the hand not holding the dop arm to apply and spread the polishing mixture, keeping same well distributed. The feel of the fingers on the lap is an excellent guide to indicate when the wheel needs cleaning or additional polishing material. The progress of the work should be frequently inspected, as it is possible to over-polish a facet, resulting in unmatched facets. The gem is kept in constant motion, swinging from side to side. Holding in one position is not advisable. Toward the end of the polishing the lap surface can be free of visible polishing powder. Enough will be embedded in the soft lap surface to continue the final polishing.

The lap surface need not be scarified, as good work can be done with a perfectly smooth surface. A razor blade will be found excellent for cleaning the surface of the lap. The tool is held on the lap while in motion. Eventually the soft tin, lead, pewter or whatever metal is used for polishing will become heavily grooved and otherwise marked. It is possible to have the surface machined down true, but if you are using the sheet metal disk type of lap it will be found less expensive to purchase a new disk. Polishing speeds of approximately 100 R.P.M. for an eight-inch lap will be found effective for all gems of less than eight in hardness. Higher speeds are generally effective only in skilled hands.



Metal V-shaped block to aid in properly aligning gem on metal dop. Variations of this device are in wide use.

A much wider assortment of polishing powders is indicated for facet work than in cabochon polishing. A great many polishing agents have been used for this work and every lapidarist has his own preferences. Where one worker may get excellent results with a given material, another operator may not find the same satisfactory, or at least not until the use of the material is mastered.

Tin oxide and tripoli have been in use for years and these agents are s-factory for some gem stones. It is perhaps possible to polish all gems with only a few abrasives, but considerable time will be consumed in some instances. The modern polishing agents are in general much more effective and are being widely adopted. These include *alumina* and *levigated alumina* (Norton Company), and *Damascus Ruby Powder* (Dixon & Company). Under separate headings the various difficult gems are described and the abrasives used given in detail.

OPTICS OF GEMS

The lapidarist should have some knowledge of light to understand the principles involved in the cutting of gem stones. Unfortunately the subject is one much neglected by both the amateur and the professional. Great skill may be achieved in matching facets perfectly; the gem highly polished; but if the angles of the facets are not ground to proper inclinations, the stones will be lacking in brilliance and beauty. An improperly cut diamond, for instance, may be cut in such a manner as to have no more "life" than a piece of glass.

In cutting a gem, the facets should be so inclined as to reflect back the greatest amount of light possible through the top of the gem. For example, a topaz or colorless quartz can be cut in such a manner as to present considerable "life" to the main crown facets. On the other hand, the table may be lifeless and appear as a "well." Again, the table may show considerable brilliance and the main crown facets lacking in sparkle. Obviously, with gems of low indices of refraction, the amount of brilliance attainable is physically limited. Therefore, the object is to incline the angles so the gem in general appears at its best.

In recent years much research work has been done and the proper angles for cutting the various gems have been established. The table appended here is based not only on the theoretical angle in reference to the optical properties of the material, but also upon numerous tests made in the laboratory. Colored stones are generally cut for color alone, brilliance being a secondary consideration. Hence, deeply colored stones are generally cut rather shallow to permit the color to show to the best advantage.

A complete and exact analysis of the paths of light through a gem is impossible. For a given condition of light source and point of observation such analysis can be made. In practice, the light enters the gem from numerous directions and the rays when leaving the stone will be viewed from many angles. If the gem were to be always viewed from the same angle, the problem of selecting the proper angles to cut would become a simple one.

The basic rules of the optics of gems are simple and readily understood. The brilliancy of any transparent solid material is dependent upon four fundamental laws of optics. These are reflection, refraction, critical angle and dispersion.

REFLECTION

Reflected light is that which strikes a reflecting surface at such an angle that the ray does not penetrate into the substance, but is reflected away at the same angle at which it strikes. The normal is a perpendicular erected at the point where the light ray strikes the surface. The "angle of incidence" is the angle with the normal perpendicular made by the light ray where it strikes a surface. Angle B, Fig. 1 shows the angle of incidence of ray A. The angle of reflection is the angle made with the normal by the reflected ray. Angle B1 is the angle of reflection of ray A, in figure 1. The angle of reflection is always equal to the angle of incidence. A ray of light passing from air into a denser medium (like a gem), is bent toward the normal, but in leaving the stone the ray of light is bent away from the normal.

REFRACTION

Various gems have the property of bending or deflecting a light ray, more or less. This "bending" is measurable and is termed the refraction of the substance. This is well illustrated in the familiar test of inserting a stick into water. The stick will appear as being "bent" or deflected, owing to the fact that the water has a different index of refraction from that of air, which is taken as a standard of one, water being slightly over one (1.33). Refraction does not take place when the light strikes the surface at exactly perpendicular (90 deg. angle). The amount of bending that takes place at the surface is not a fixed value for each material but varies with the angle of incidence, ranging from no bending when the ray enters at 90° from the surface to as much as 50° if it strikes near the parallel surface. The angle of refraction is never equal to the angle of incidence, but is always greater or smaller than the angle of incidence. In Fig. 1, D-1 is never equal to angle D.

Thus the refractive index of a gem is the indication of the amount that a ray of light will bend when leaving air and entering a denser substance. For example, quartz with a refractive index (R. I.) of 1.54 and 1.53 and diamond with an R. I. of 2.42, there is a considerable difference in the manner in which light is affected. This in a large measure accounts for the fact that it is possible to get considerable brilliance from a diamond and relatively little from clear colorless quartz. Likewise, colorless zircon with R. I. of 1.92 and 1.96 will yield a stone of considerable "fire," approaching that of diamond. Hence, it is highly important that the R. I. of a gem be taken into consideration when cutting the angles of the facets. Since certain gems fall into similar groups of refraction it is possible to assign a set of angles for the facets, as shown in the table appended here.

CRITICAL ANGLE

Every ray of light striking the surface of a gem will not be again passed out at the crown portion for various reasons. A certain portion of the light entering the crown portion may be lost in the pavilion of the stone. The ray of light passing through the gem must be caught by the pavilion facets at more than the critical angle. Thus a stone cut with proper crown facet angles, but with improper pavilion facets, would tend to appear lifeless.

The critical angle is the angle with the normal, at which light traveling in a gem and striking a surface (facet) will neither be returned by reflection into the gem, nor will pass out into the air but will travel along the line of the surface of the stone. Light traveling within a gem, striking a facet surface at less than critical angle, emerges from stone. Striking at greater than critical angle, is reflected within the gem.

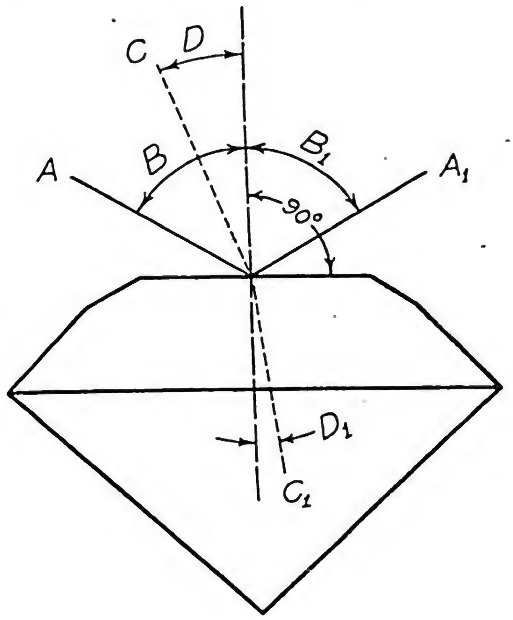


Fig. 1

The formula for finding the critical angle is $\frac{1}{\text{R. I.}}$ = sine of the critical angle. A sine table will give the angle degree of the resulting sine figure.

The amount of bending or refraction that takes place in the gem is calculated by the formula:

$$\frac{\text{Sine of angle of incidence}}{\text{R. I.}} = \text{sine of}$$

angle of refraction. Refer to sign table for angle degree. Standard text books on mineralogy and gemmology will give the reader detailed explanation of the various phenomena.

DISPERSION

The remarkable color play seen in the diamond, zircon and other gems is due to dispersion. White light, such as sunlight, is composed of many colored light rays, but we only perceive these when the white light is broken down into its component parts. The spectrum produced by a prism (Fig. 2) is a good illustration. Like other optical phenomena, the amount of dispersions will vary with the various gems.

CALCULATING ANGLES

It is a simple matter to measure the angles of a cut gem and, using these angles, make a drawing as shown in Fig. 3. This illustration shows an improperly Oriental cut zircon, with the main crown facets at 46 deg., the crown

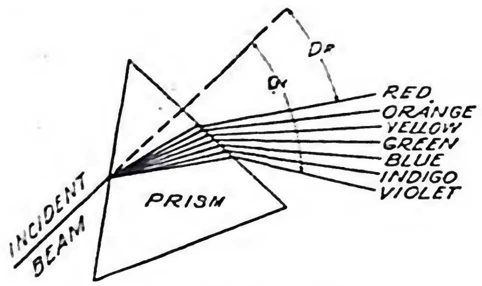


Fig. 2. Illustrating the manner in which ordinary white light is split up into its component parts by passing through a glass prism.

table facets at 28 deg. and the main pavilion facets cut at 42 deg. Ray A strikes the table at normal; therefore it is not refracted, but passes straight through until striking the surface of the pavilion facet at 42 deg. This angle being greater than the critical angle (30+ deg.), the ray is reflected across to the opposite pavilion facet at 42° and striking at 54° it is then reflected at 54° out through the crown of the gem, bending 33° away from normal.

In Fig. 3, ray B strikes table facet at 28 deg. from normal, and is bent 14 deg. toward normal as it enters the gem. From this point ray B is treated in the same manner as ray A. Ray C enter main crown facet at 46 deg., is bent 21 deg. toward normal, striking first pavilion facet at 77 deg. and reflected to second facet at 24 deg., which, being less than the critical angle, allows the ray to pass out, bending away from normal at 54 deg. This diagram indicated that when calculations are made with light entering gem at normal table, all light entering through m facets is lost in the pavilion.

This Oriental cut zircon can be gre ly improved by changing the angles the main crown facets to approxima 43 deg. and the main pavilion facets 41 deg.

The purpose of this description a the illustrations is to enable you to termine gem stone angles by tracing

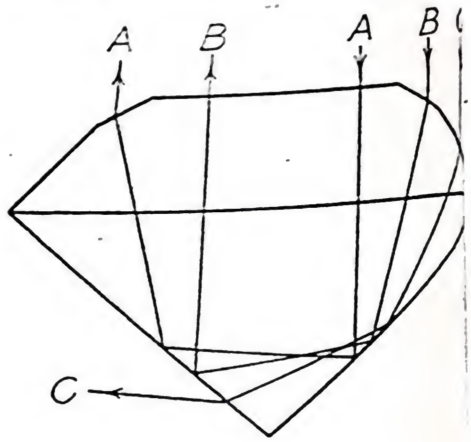


Fig. 3

Fig. 3. Illustrating the passage of rays light through a brilliant style facet cut ge stone. See text for explanations.

paths of light, and then cut the gem a your own calculations. Drawing can b best made at least eight inches in siz to better follow the various paths. Au thorities will vary as to the best angle at which to cut gems, and each cutte usually follows what he thinks best a learned by experience and study.

The illustrations given here of th various styles of cut show those use in the past and at present. The olde methods and styles gave little attentio to proper angles, and with the very stee angles employed the gems were fre quently dull and gave but a small per centage of the possible brilliance. In designing brilliant cuts, it is well to use the main crown and pavilion facets for your angle calculations. Table and girdle facets are much smaller than the main facets, and while they play their role reflecting light, they are mainly used for decorative purposes. In making calculations for the trap cut styles the same rules apply. Do not expect as much brilliancy from the trap or step cuts. These can be best applied to gems of low refractive index, but rich in color.

FACET ANGLES FOR CUT GEMS

	R. I.	Facet	Angles
Diamond	2.42	C. 35°	P. 41°
Zircon	1.92	C. 43°	P. 41°
Garnet—			
Demantoid	1.88	C. 43°	P. 40°
Spessarite	1.81	C. 43°	P. 40°
Almandine	1.79	C. 37°	P. 42°
Rhodolite	1.76	C. 37°	P. 42°
Pyrope	1.75	C. 37°	P. 42°
Hessonite	1.74	C. 37°	P. 42°
Andradite	.....	C. 37°	P. 42°
Uvarovite	.....	C. 37°	P. 42°
Benitoite	1.75	C. 37°	P. 42°
Chrysoberyl	1.74	C. 37°	P. 42°
Sapphire	1.76	C. 37°	P. 42°
Epidote	1.73	C. 37°	P. 42°
Spinel	1.72	C. 37°	P. 42°
Diopsite	1.68	C. 43°	P. 39°
Peridot	1.66	C. 43°	P. 39°
Phenacite	1.65	C. 43°	P. 39°
Kunzite	1.65	C. 43°	P. 39°
Tourmaline	1.62	C. 43°	P. 39°
Topaz	1.61	C. 43°	P. 39°
Beryl (all varieties)	1.57	C. 45°	P. 41°
Quartz (all varieties)	1.54	C. 45°	P. 41°

R. I.—Refractive index, *only the lower one given* where there are more than one. C—Main crown facets. P—Main pavilion facets.

In the above table only the principal facet cut gems are listed. Any gem not listed can be fitted into table by reference to its refractive index, using the lower one if there are two.

As the index of refraction of a gem stone decreases, less light is returned through the crown of the gem. Hence the lower the index of refraction of the material the less brilliancy will be possible. All stones having an R. I. of less than 1.65 will show a "well" or dull spots are some place on the crown.

GINKGO TREES

The Rancheo Santa Anita, at their Baldwin Park, in Arcadia have six splendid and thriving specimens of the only surviving ginkgo (Ginkgo Biloba), reports General Manager Clifton B. Herd. The tree appears to grow exceptionally well at Baldwin Park, which is near Los Angeles and open to visitors.

Gold deposits are often larger and richer near the surface than at depth.

SYSTEM FOR FACET CUTTING GEM STONES

FOR STANDARD BRILLIANT

In any technic used for the cutting and polishing of facet cut gems, a definite system should be followed in working the stone. Experienced workers may use a different procedure, but the one given below has been found satisfactory. In enumerating the below outline, detailed reasons are not given in all instances, for some are quite obvious.

(1) The material to be facet cut is first oriented in accordance with the direction of the optic or crystal axis of the material, and then roughed out to the desired shape on the grinding wheels. Leave enough excess material at the girdle and on the crown and pavilion to allow for the small amount removed when the facets are cut. Skilled fingers can do this grinding by holding in the hand, or the stone can be dopped.

(2) The rough blank is then cemented to the metal dop, placing the stone so the table portion is at an angle of about 45 degrees to the axis of the dop. Or a contra-angle dop may be used.

(3) Mount in the facet cutting device and lap down the table to about 10% oversize. The table is fully polished before the gem is removed from the cement.

(4) Re-cement the stone to dop, with the table at exactly (near as possible) right angles to the length of the dop. The 8 main crown facets (above girdle) are then cut. For a number of mechanical reasons the 8 main crown facets are not cut in consecutive order, but in staggered order—1 - 5 - 3 - 7 - 6 - 2 - 8 - 4. In short, something like the firing order of your V-8. There are good reasons in both cases. By the use of the above method or some similar system, it will be easier to line up the angles at which the facets meet and to keep them uniform in size, and to aid in eliminating overcutting or under cutting. This system of course is applicable only to the standard brilliant cut; but similar methods will suggest themselves for other style cuts. In placing the 8 main crown facets the correct angle for the material in hand is noted on the scale of the facet cutting head.

(5) The 16-crown girdle facets are next cut, extending them about two-thirds of the distance toward the table. Only a very slight change in angle is made for this row of facets.

(6) The 8 small crown table facets, adjoining the table, are now cut by reducing an edge of each main crown facet.

(7) You now have cut 32 facets (excluding table) on the crown portion of the gem (above the girdle). After all silicon carbide or *Norbide* is washed from the stone and dop, polishing is in order. The crown facets are polished in the following order: (a) 8 crown table facets, (b) main facets, (c) girdle facets. Like in cutting the facets,

there are mechanical reasons for this order.

(8) The stone is removed from the dop, and re-cemented with the pavilion portion exposed for cutting. Care should be taken to again mount the stone with the table at right angles to the length of the dop; this is to avoid a lop-sided finished stone. The mechanical dopping aids shown here will assist the beginner in properly mounting the gem.

(9) The 8 main pavilion facets are then cut, taking care to line up number one facet with one of the main crown facets, and then proceed with the "firing" order given above.

(10) Next the 19 pavilion facets (adjoining the girdle) are cut. The standard brilliant style calls for 57 facets, including the table, but sometimes 8 culet facets are placed on the stone, making a total of 65 facets. Other variations in the brilliant style can be made to give an even greater number of facets, sometimes an extra row of facets is placed on the crown portion.

(11) The polishing order for the facets below the girdle is: (a) culet facets (at "bottom" of gem), (b) main facets, (c) pavilion girdle facets.

The above system will serve as a basis for any style of cut having a table. Fancy styles where the gem has no regular table will require individual study on the part of the lapidarist. The native Oriental cutter, in shaping a stone solely for weight, will pay no attention to any methodical system, but will proceed to slap on facets regardless of the number in a row. The result is generally a gem lacking in uniformity and brilliance and will require re-cutting before being sold to the retailer.

One of the most important phases of facet cutting is the preliminary determination of the size of the table, for this will to a large extent govern the remainder of the work. For instance, the 8 crown table facets extend downward to join the angle of the girdle facets; if the table is out of proportion this will lead to mechanical difficulties, in addition to an unbalanced stone.

The main crown and pavilion facet angles will determine the angles of the various rows of small facets, in the standard brilliant cut. If you are working with spinel and cut the main crown facets to 37 degrees, and the main pavilion facets to 41 degrees, and if the table is correctly proportioned, you need not give special attention to the angles of the lesser facets; a few degrees difference will suffice. The size of the table in proportion to the other dimensions of the stone, and the proper joining of the various rows of facets, will naturally govern the angles of the minor facets.

In cutting the rows of facets on the crown portion, the main facets are "split" to obtain the 8 table facets, while the 8 main facets are "divided" to secure the 16 girdle facets.

Various mechanical means are used to hold the stone while being cut, and to obtain correct angles, and spacing of the facets; these devices range from the old "stick and jamb peg" to the more modern and refined devices. Some commercial facet cutters have developed so much skill they are enabled to do excellent work by merely holding the dop into a notch made in a rigid upright post, the various notches giving the different angles. For the less skilled worker and the beginner, some more highly developed mechanical aid is indicated. Numerous amateur lapidarists, throughout the country, are doing very creditable facet cutting work.

Facet cutting will always require more practice and skill compared to cabochon cutting, for the human hand and eye must guide and control the work, regardless of mechanical aids. However, it has been amply shown that with even inferior equipment, the individual cutting gem stones as a hobby can by persistence and practice master the art of facet cutting and do excellent work. All gems other than diamond can be utilized.

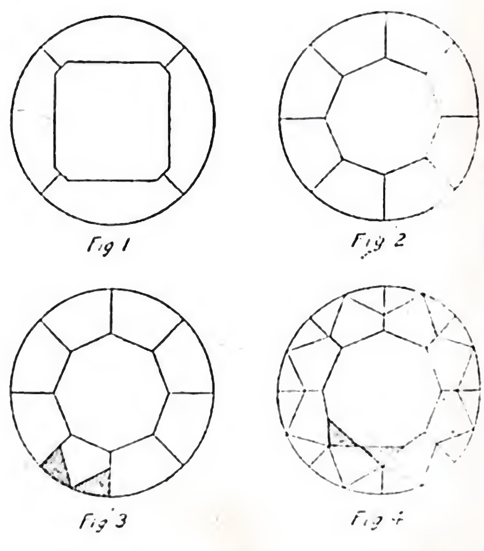


Fig. 1. Table cut and polished (oversize), and four main facets cut on gem. Fig. 2. Main facets divided to give eight main crown facets. Fig. 3. (Shaded portion) Showing extent and correct position of crown girdle facets. Fig. 4. Position of crown table facets for standard brilliant style.

Diamond requires special equipment, generally outside of the amateur field, and is not referred to in this work. It is felt that lack of suitable equipment, guidance, technical information has in the past hindered many in making more rapid progress, or even attempting the fascinating art of facet cutting. Now with thousands of "amateur" workers throughout the country it is easily possible to actually see the technic of facet cutting, and questions will usually be answered freely by the amateur. Frequently seeing the work done after reading the technic is a great help and advantage. THE MINERALOGIST Magazine, Gem Cutting Laboratories, 70? Couch Building, Portland, Oregon, are open to the public, *by appointment.* Questions are freely answered to those who are seriously interested and every possible aid will be extended. It is generally not possible to get this service from commercial establishments, at least not where facet cutting is being done.

FACET CUT TOPAZ

Topaz presents some difficulties in polishing for a number of reasons, especially in stones with a large table or numerous large facets. Since topaz has a relatively low index of refraction the amount of brilliance and life that can be had from a brilliant style colorless topaz will be necessarily limited. However, good colorless topaz shows much more "life" than quartz and can be more widely utilized by gem cutters.

ANGLES

In order to get the greatest brilliancy from colorless topaz, in the standard brilliant cut, it is desirable to have the table as nearly parallel to the basal cleavage as is possible. In dealing with colored topaz, orientation of the table in relation to the basal cleavage and long crystal axis is not nearly so important for here we are concerned mainly with bringing out the best color.

Topaz can be cut to certain angles (in brilliant style) where the table will show at its best, but on the other hand the surrounding crown facets will appear dead and lack in sparkle. Again the angle may be altered to bring out the crown facets but in looking down on the gem there will appear to be a "well" in the table. The lapidarist generally selects angles which will strike an average, so neither the table or the remainder of the facets will appear unduly prominent, to the detriment of the gem as a whole. A good average cut can be had by placing the main crown facets at an angle of 43 degrees and the main pavilion facets at 39 degrees. With these angles the "well" in the table will be reduced to a minimum, but not entirely eliminated. No culet facets should be used, as this will only accentuate the well in the table.

The basal cleavage of topaz is very marked, hence it is next to impossible to polish a large table resting exactly parallel to this cleavage direction. The material will pit and slough away in a most annoying fashion, often when the surface is nearly polished. As an alternative some lapidarists will complete the final polish on a large table by the use of a hard felt buff, and then polish the remainder of the facets in the usual manner. The felt buff tends to produce a slightly curving surface which is not at all desirable, and which tends to detract from the brilliance. In order to eliminate the difficulties encountered on the cleavage, lapidarists generally orient the table at a slight angle to the basal cleavage. This orientation will vary with different cutters, but from three to five degrees appears best. This slight angle of the table surface in relation to the cleavage does not appear to detract noticeably from the appearance of the finished stone. Where the basal cleavage is present on the rough crystal, the table can be oriented at exactly right angles, during the roughing out process. When the stone is mounted on the dop, an angle of from three to five degrees can then be set, ground away, and the surface polished in this position.

POLISHING TOPAZ

A large number of polishing agents have been advised for the polishing of topaz. A number of these were tried in the Gem Cutting Laboratories of THE MINERALOGIST Magazine. The polishing agents tried and found satisfactory include Damascus "Ruby" Powder, Levigated Alumina and Buffing Powder Grade A No. 1 coarse. Some gem stone cutters find tin oxide a satisfactory polishing agent for topaz. Seemingly a slightly different "touch" and skill is required with the various polishing agents, and it is only natural that every operator will develop the needed skill with some particular material.

Various speeds are advised for polishing topaz. This is true for all other gems which are cut facet. In general the "amateur" facet cutter will find the slower speeds best suited for his skill. An eight-inch lap revolving at approximately 100 R.P.M. will give best results for topaz and practically all the other facet cut stones. The speed of the lap and the kind of metal used appears to be more important than the selection of the polishing agent.

Various metal laps are in use in the lapidary industry, but pewter and tin appear to be the favorites for polishing topaz and similar gems.

POLISHING ZIRCON

The gem stone zircon with its high index of refraction and remarkable variations in color is a highly popular stone. The blue-green types ("Starlite") were first generally introduced into the jewelry trade some twelve years ago, to meet with instant popularity. Most of the blue and colorless stones have been put through some form of heat treatment to enhance or alter the color, but this in no way affects the beauty and sparkle of the gem. A good colorless zircon has a "fire" nearly equal to that of diamond, and under artificial light it will readily pass for the Prince of Gems, under the gaze of the casual observer.

Zircon is generally considered a difficult stone to polish in facet cut styles. It tends to "pit" during the final stages of polishing. Polishing agents effective for zircon include *Buffing Powder*, grade A, No. 1, coarse, and *Damascus Ruby* powder.

The pewter and tin laps are most effective and should be operated at slow speeds, approximating 100 R.P.M. for an eight-inch lap. The above polishing agents, laps, and speed will also be found effective for quartz, spinel, topaz, and peridot.

HARD AREAS IN GEMS

In the cutting and polishing of some facet gems hard areas may be encountered, which may give added difficulties in cutting and polishing. In cutting and polishing of sapphire, particularly Montana material, this effect will be noted. Frequently the hard areas on sapphire will require from five to ten times as long to polish as the normal facet. The diamond charged lap has long been the favorite with lapidarists for the purpose of cutting facets on sapphire, but *Norbide* has now largely replaced diamond. The new abrasive is considerably harder than sapphire and no difficulty will be encountered in readily placing facets with *Norbide*, even in the harder areas. The difficulty will come in the polishing.

Hard areas will be encountered in virtually all hard gem materials which occur in the crystallized form, but by the use of silicon carbide or *Norbide*, no difficulty will be experienced in the cutting of facets on any gem of nine or less in hardness. When the hard areas are encountered in polishing there is little than can be done other than to clean the surface of the lap and apply fresh polishing powder and continue the work.

The hard areas are due to some form of twinning or distortion in crystal growth and can be compared to a knotty growth in wood. One outstanding instance of an extremely hard gem is the record of the diamond that failed to yield to all cutting technic after six months of effort, when the diamond cutter gave up the task as impossible. Obviously this diamond was slightly harder than ordinary diamonds, and since no harder abrasive was available cutting was impossible.

Twinning and distortion in a crystal growth and laminations may present not only slightly harder areas, but a structure which is harder to polish. The facet surface may tend to "slough." Topaz has a very marked cleavage at right angles to the optic axis of the crystal. This cleavage is seen parallel to the basal cleavage, and if the gem is oriented so the table is exactly on this plane, considerable difficulty may be encountered in polishing a large table.

HOW DOUBLETS ARE MADE

Thin sections of various materials cemented together and then cut to proper shape are termed doublets or triplets, according to the number of sections. Facet cut stones like emerald are sometimes made in doublets and triplets, with a thin portion of emerald forming the crown portion of the gem. Stones of this type are usually manufactured in the cutting centers of Europe.

The home lapidarist can easily make excellent doublets of cabochon stones like opal. Frequently Australian opal occurs in very thin seams of flashing "fire," for which a backing to add strength and bulk to the gem is desirable. Fire opal can be backed with common opal or some more durable stone like dark colored agate or iridescent obsidian.

The laboratory of THE MINERALOGIST magazine has developed a method of backing an opal with dark colored iridescent obsidian. This backing is inexpensive, about the same hardness as the opal, and leaves a pleasing appearance to the reverse side of the gem.

To make an opal doublet, grind down flat the "back" side of the gem, exposing the seam of "fire" on the face of the stone. Then grind down flat a similar sized piece of iridescent obsidian (or other backing), and cement the two portions together, using *Dixon's* Black enamel cement or any regular doublet cement. The two portions can be of irregular shape, as the final grinding and shaping is done after the two portions are cemented. By this means very thin and otherwise fragile fragments of opals can be utilized with good effect. Many of the less costly opals sold in the trade are doublets, especially the "black" types of opal. Doublets when sold as such are not frauds. In the case of opal the backing is frequently added merely to give strength. In some types of translucent opal the backing of black iridescent opal adds greatly to the beauty of the stone.

GRINDING THIN SECTIONS

Fossil wood, minerals, rocks and gem minerals are often reduced to very thin sections to enable examination with the microscope. In general the grinding of thin sections is no more difficult from a lapidary standpoint than the cutting of a cabochon. Rather, the difficulty is encountered in the lapping of rock sections, which may be quite friable, and which must be checked at intervals for proper thickness by the aid of a polarizing microscope. Fossil woods and well consolidated transparent minerals do not present these difficulties, to the same extent, as here we are not dealing with a mixture of minerals (like in rock sections).

Petrified (fossil) woods can sometimes be determined without the aid of a thin section, by merely examining the polished surface of a specimen. A low power hand lens will aid. Some types of fossil wood can be definitely determined only in the thin section, examined by a low power microscope. Sometimes a great deal can be learned of the structure of a gem mineral and its optical properties through the aid of the thin section. It is not within the scope of this work to include data on the determinations to be made on thin sections. The reader is referred to standard works on optical mineralogy. An ordinary microscope will suffice for the determination of petrified wood, polarizing instruments are not needed.

SAWING

If a thin section is desired from a large specimen, or if an oriented section is required, sawing will be the first procedure. This can be done by any of the saws employed for lapidary work. It is advisable to cut as thin a slice as possible, for this will eliminate subsequent labor of further reduction.

GRINDING

The cut section, or the rough fragment, is further reduced as much as possible, using the sides of the grinding wheels, in order to obtain flat, smooth surfaces. A hard, compact fragment can be cut quite thin on the grinding wheels without fracturing, using the same care as in handling any delicate gem stone. The horizontal running lap, charged with No. 120 grit silicon carbide or *Norbide* (harder), can also be used in an effective manner for the production of thin sections. For all ordinary purposes the section need not be over half an inch square on the surface.

LAPPING

When the section has been reduced quite thin, one side of the specimen is made smooth by a slight amount of grinding with No. 500 or No. 600 grit silicon carbide or *Norbide*. This can be best done by hand labor, using a flat surface of glass, charged with the fine abrasives, mixed with water. One finger will give enough pressure and the section should be given a circular motion.

CEMENTING

The finished side of the section is then cemented to a microscope slide by the use of liquid canada balsam. A drop or two of the cement is sufficient. The slide is pressed down and placed on a plate or in an oven to "cook." A temperature of close to boiling is required to hasten the setting of the balsam. This will require about an hour. If higher temperatures are used the balsam will boil and make an unsatisfactory mount, while low temperatures will require longer to "set" the balsam. A hot plate can be used to heat the slides, or they can be placed under a strong electric light, fitted with a metal shade. The main point is to get a near-boiling temperature for an hour or longer.

With the thin section now firmly cemented to the slide, it can be examined by holding toward a strong light or under the microscope, in order to determine how much additional lapping is needed. The section must be reduced to a point where light will pass through, thus enabling viewing the interior as well as surface structure. Dark or opaque petrified wood must often be reduced to about 1/1,000th of an inch in thickness; rock sections even less; but the transluscent opalized or agatized woods need not be ground as thin. Practice will determine the amount of grinding required. If a large amount of material must be removed, start with No. 220 grit, and when the bulk has been removed pass on to No. 500 or No. 600 grit. This work can be done best by hand, on the glass plate, as stated above. A horizontal lap can be used at the start, but the final lapping must be done by hand. In some cases a section must be made so thin that several more revolutions on the glass plate would completely remove the section. Hence care and gentle pressure must be used in the final stages.

PERMANENT MOUNTS

If a permanent mount is not desired the specimen can be now examined and studied under the microscope. For permanent mountings, a thin cover glass is cemented over the section, using canada balsam and heat in the usual manner. In lapping operations, the ends of the glass slide may become abraded or "frosted," but this will in no way affect the viewing of the section. If slides of about 50 mm. length are used this will be largely eliminated. A short length section is also easier to handle on the rotating stage of a polarizing microscope.

SLIDE COLLECTIONS

The lapidarist is well equipped to acquire collections of microscopical slides. A series of slides made from petrified woods are valuable for study and comparative purposes. Sections of gem minerals are also of use and value. It is next to impossible to definitely classify some rocks without the aid of thin sections. Here again a collection of rock slides is of consideable value for study purposes. Like micro-mounts of minerals, slide collections occupy little space, are easily portable and of definite value.

CAMEO CUTTING AND CARVING

Cameo cutting and gem stone carving and engraving is an art requiring considerable skill, in order to produce artistic work on hard gems. Mounted silicon carbide wheels and points (vitrified) can be used to good effect in working the harder gems. Those softer than steel can, of course, be cut and engraved by the use of engraver's tools.

A portable, high-speed grinder, in which the points and wheels can be mounted, is very useful for cutting and engraving. The work is held in a padded vise and the grinder held by hand. Small soft metal points charged with silicon carbide, *Norbide*, or diamond are also effective in some types of cameo cutting and carving. The fine grits of silicon carbide are used to smooth the work, after the heavy cutting is completed. Small hardwood points are also used to carry both cutting and polishing abrasives to the work.

DRILLING HOLES

Holes are sometimes drilled through a gem stone to render it suitable for some ornamental purposes. Soft gems like malachite and turquoise can be drilled with small steel drills (dentist's type), but the harder gems require different technic. There are two types of drilling, one being done by the use of metal tubing, the other by a diamond point.

TUBE DRILLING

Small holes can be sunk by the use of a small section of jeweler's drill tube and silicon carbide made into a paste with oil. The new hard abrasive, *Norbide*, will work faster than silicon carbide, especially when dealing with hard substances. Small holes can be worked by the use of fine grit No. 220 to No. 320, depending upon the depth of the hole. The soft metal tubing is slightly flattened on the cutting end (cut clearance), mounted in a small drill press and fed with gentle pressure. Diamond dust, as is used for sawing, can be used as an abrasive with good effect.

Large holes can be cut with the proper gauge iron, copper, or brass tubing, keeping the cutting end slightly flat by gentle tapping with a light hammer. If the end of the tube drill fails to cut clearance for the core, it will jam and possibly lodge fast in the work. The tube must also cut a hole slightly larger than its outer diameter, to prevent wedging fast. Silicon carbide or *Norbide* or No. 120 grit is generally employed for larger holes.

By the use of two large sized tubes, one slightly smaller than the other, it is possible to cut a circular band from a flat piece of agate or jade, or any tough gem material. These are worn as a finger ring. To produce a ring of this kind, a hole of proper size (finger diameter) is first made in a flat polished piece of the material. The slightly larger tube is then used to cut the ring free of the surrounding matrix. Rings can be cut from flat sections of iron meteorites by this means. In drilling any type of hole, with either tube drills or diamond mounted points, it is advisable to clamp the work rigidly to a secure base, below the drill.

Some years ago, when the huge agatized dinosaur skeleton was mounted at the Field Museum, it was necessary to first sink large holes through the thick agatized bones, to enable articulation by passing cables through the holes. Some of the bones were of considerable thickness and fully agatized. They presented a problem in tube drilling. Ordinary iron pipes were used, with silicon carbide as the abrasive, and while the work was slow, numerous holes were drilled without any difficulty. It was found important to keep the ends of the pipe slightly blunt by hammering at intervals.

DIAMOND DRILLING

Small holes can be sunk by the use of commercial diamond drilling points. These are mounted and ready for use. Diamond drills are generally utilized for the commercial drilling of beads where speed is a factor in production. The diamond drill is a delicate tool and requires care and skill in use.

CUTTING SLOTS

Where a square or rectangular shaped hole is desired, this can best be accomplished by the use of small mounted silicon carbide points of the same type as are used for cameo cutting and engraving. Mounted points and small wheels are effective where the stone is not over a quarter of an inch in thickness. The slot can be worked from both sides.

OVERLOADING DANGEROUS

Attention is here called to the danger of placing too large a grinding wheel on a small diameter grinding arbor or spindle. Instances are known where a 12 inch grinding wheel has been mounted on a one-quarter or one-half inch spindle, and in operating at standard speed, would be torn off thus releasing the whirling wheel. This practice is fraught with danger.

Below are given *minimum* safe spindle sizes, as stated in the Norton Company Data Book.

6x1 inch wheel—½ inch spindle.
9x1 inch wheel—¾ inch spindle.
12x1 inch wheel—1 inch spindle.
20x1 inch wheel—1½ inch spindle.

The above spindle sizes are given for a maximum operating speed of 7,000 surface feet per minute, the standard speed used being 5,500 S.F.P.M.

In the use of wet grinding wheels do not permit a wheel to stand partially immersed in water for a period of time. The water soaked portion being heavier may throw the wheel dangerously out of balance. If a wheel has been subjected to rough handling in shipping a crack may develop, hence in starting a new wheel in operation, stand to one side until after full wheel speed has developed for a few minutes. Do not remove the washers of blotting paper which are placed at the factory, this compressible material is placed there for a good reason, it is not merely ornamental. When tightening arbor (spindle) end nuts do not use more pressure than to hold the wheel firmly.

CRUSHING MORTAR

While diamond bort, used in diamond sawing, can be purchased ready crushed to the approximate size, a mortar suitable for crushing can be readily made.

Place the diamond fragments to be crushed on a punch block, or any piece of iron with a smooth flat surface. Place over the diamond an ordinary pipe nipple, from three to six inches long. For a pestle, use any piece of round steel that will pass freely into the pipe; a cold chisel, head down will answer. Crush the diamond to proper size by striking the pestle with a hammer. Remove the pipe, and with the face of the hammer, rub the fragments to any desired degree of fineness. A little experience will tell what fineness is best for charging the saw, generally from 100 to 120 grit is used.

GRINDING WHEEL HINTS

In other industries where silicon carbide grinding wheels are used, close attention is given to the proper use of these tools. An improper wheel for the purpose at hand will mean loss of efficiency and waste. Moreover, the wheel should not be subjected to abuse.

All lapidary grinding wheels should be run at the proper surface speed for the size of the wheel. If you cannot meet this requirement it can be compensated for to some extent by using a *harder* bond for the reduced speeds.

As a general principle of grinding the more points of contact between the work and the wheels the more heat generated and the *slower* the cutting. This probably accounts for the fact that lapping down a large flat surface proceeds slowly. The general rule to follow is to use a wheel of as coarse a grit as possible and with as hard a bond as possible without *bumping,* instead of *grinding.*

Bonds too hard for the work at hand hold the grains in the wheel after the fragments are *dull.* Bonds too soft for the material permit the wheel to *ravel* and slough away. Although fast cutting may be had, it will be at the expense of the wheel, and does not make for economy. Thus, if a soft bond wheel is used to grind sapphires to shape, the work will proceed fast enough, but the wheel may show an alarming amount of wear, a harder bond is indicated in this case. If a great deal of one type of gem material is being cut in a commercial establishment, a little study and observation will indicate the proper grit and bond to spell wheel economy and yet reasonably fast production.

With regard to using a rest for the arm and hand, small fragments can be ground satisfactorily with little or no armrest. But when large masses are being worked which approach or exceed in weight the bulk of the wheel, it quite a different matter. For large masses the wheel should be quite true and a rigid hand and armrest provided.

Wheels becoming untrue or eccentric to the point where they "bump" is largely the fault of the operator, regardless of wheel grit and bonding. The most important factor in keeping a grinding wheel in good condition is a rigid hand and armrest when working any hard material. Use only moderate pressure against the wheel, especially when starting to grind off a sharp corner, and always move the work back and forth across the periphery of the wheel.

No grinding wheel can be made that will run absolutely true at all speeds, it being impossible to manufacture a wheel that will balance perfectly in all positions. Try this out by placing a twelve-inch wheel on the arbor. When run slowly it will run true. Now operate a little faster and you will note the "heavy" side will run "high." Continue to run the wheel faster until you pass what is called the *critical speed,* where the wheel "changes over" and runs on its center of gravity, with the "light" side of the wheel running "high." This is one of the principal reasons why the manufacturer advises certain speeds of wheel operation.

True enough, good wheels are not "off" very much, but they all contain the element of vibration as transmitted by the play in the bearings and the wheel itself. Now if a mass of comparable weight to the wheel has flexible suspension (hand holding), and pressure against the wheel, it is easy to see that the vibrations, or, rather, reactions between the two, will be in time with the wheel revolutions. Continued bumping of the same spot will soon start raveling, which only grows worse with use unless the wheel is dressed and trued. It is nothing uncommon to note a twelve-inch grinding wheel a quarter inch eccentric from this abuse, but you may be sure it does not cut accurately or economically under these conditions.

An eight-inch grinding wheel on a half or three-quarter inch spindle is a *delicate tool* and the man who imagines he is a foundry bucko grinding a heavy casting against a 36x4-inch wheel is bound to have wheel trouble no matter what the grain, speed or bonding of his small wheel may be. Give your grinding wheels the opportunity to cut and avoid excessive heavy pressures. After all, there is a definite limit to the speed at which any wheel will cut effectively.

COMPARATIVE HARDNESS OF STONES

The comparative hardness of gem minerals is difficult to determine (by hand testing) where there is only a slight variation. It is, however, a simple matter to separate those which vary one degree or more, like quartz from topaz. Hardness testing can be best carried out with special points made for that purpose. These are more satisfactory than attempting to place a scratch with a large blunt point. Tests made on a smooth surface can be examined with a low power glass to note any scratching. Valuable gems should be handled with care. The girdle is the place generally tested for hardness. The slight "dust" of abrasion should not be confused with an actual scratch.

Moh's scale of hardness, used in all standard texts on mineralogy, fails to properly indicate the actual difference between the various gems. On Moh's scale, sapphire is listed as nine and diamond as ten, but the latter is actually at least *ten times* harder. The tables below may serve to show the actual differences:

	Moh's	*Gem Scale*
Diamond	10	10,000
Norbide	9½	4,000
Sapphire	9	1,000
Topaz	8	450
Zircon	7½	350
Quartz	7	250
Agate (average)		225
Steel file		200
Opal (variable)		150
Knife blade		100
Glass (variable)		100
Malachite		0
Calcite		90

Two of the most characteristic, easily determinable, physical properties of a gem mineral are its specific gravity and hardness. Frequently either or both of these properties can be determined in a matter of a few minutes. There is a slight variation in both the gravity and hardness of most gem minerals, as noted elsewhere. The many varieties and sub-varieties of quartz are not listed. These are covered under chalcedony and quartz.

TESTING GEM STONES

The lapidarist will frequently be called upon to pass judgment upon the identity of some specimen, either in the form of a cut stone or a rough mineral fragment. In some instances a simple test will serve definitely to correctly name the gem, while in other instances a determination may be beset with considerable difficulty and doubt. The purpose of this chapter is not to present any detailed directions for the identification of all gem minerals, but to list only the more simple and general tests within the scope of the amateur.

MANY IMITATIONS

It has often been stated that modern science has been successful in the manufacture of passable imitations of every gem stone known with the exception of opal. From the standpoint of the layman, this statement is quite true, for imitations of practically every gem are sold daily under some guise or other. Diamond has so far not been manufactured on a commercial scale, but a good quality white zircon can pass the inexperienced eye for the real article. Of all gem stone imitations, those sold as "opal" are perhaps the most miserable and easily detectable of all. In all probability science will never succeed in the manufacture of a successful imitation opal.

Glass of various colors, hardness and index of refraction is one of the most common of all imitations. It is cheap, can be made in any color, and with sufficient index of refraction to give it brilliance and "life." Fortunately, since glass is a fused substance, lacking in crystal structure, its determination is usually a simple matter.

METHODS OF DETERMINATION

In testing a gem stone or gem mineral, advantage is taken of various properties of the mineral, principally its physical and optical properties and crystallographic form. If the rough material shows crystal form, it can generally be immediately recognized on sight, if the lapidarist is famlliar with the crystal form of the gem minerals.

In general, a rough fragment is much more easy to identify than the cut stone, as in the former case tests can be applied without fear of damage to a possibly valuable gem. Small mounted gems may also present a special problem, and in some cases cannot be definitely determined without removing from the mounting.

Unquestionably the most difficult of all gems to determine are the synthetic sapphire types. These fused products made in the flame of a very hot blow torch, so closely resemble the natural sapphire as to render definite determination very difficult and often uncertain. Synthetic sapphire (and ruby) was introduced about fifty years ago. When first manufactured the product was crudely made, full of air bubbles and other imperfections, which could be seen by the naked eye or a low power jeweler's magnifying glass (a loupe, about eight power). However, in recent years the manufacture of synthetic sapphire and spinel has reached a very high state of perfection. Even under high powers, circular bubbles, fusion markings and other indications of manufacture are not readily seen.

COLOR

Since many species of gem stones present a wide range of colors and shades this property is one of the least valuable as a criterion of identity. Color is important in determining the value of a gem, but otherwise it is only of incidental worth as a guide to identity.

Most of the colored gem stones owe their color to minute amounts of some metallic salts present as an "impurity." This is especially true of the translucent types. Gems like azurite, malachite, turquoise and chrysocolla are, of course, colored by their inherent chemical constituents. In some instances the cause of color in a gem stone is a matter of doubt. A good deal has been written on the common gems, amethyst and smoky quartz, yet the cause of their color is not a settled scientific fact.

HARDNESS

The test for hardness is not always a reliable guide, especially where a distinction is to be made between gems that vary only slightly. A steel file or a sharp corundum point in the hands of an expert can judge closely the hardness of a gem mineral, but the practice of rubbing a large blunt mass on the rough surface of some other mineral is wholly unreliable.

If the hardness test is to be of any value it must be done carefully, preferably on a smooth, flat surface, using a sharp testing point, and the surface examined closely for any scratches. Quartz can be readily distinguished from a mineral of superior hardness like topaz, but if the variation is only ¼ or ½ degree (Moh's), distinction might be doubtful.

Hardness tests made under mechanical control are much more reliable than those made by holding the material by hand. The controlled testing machines drop a diamond point upon the substance to be tested and the indentation is measured. Or a diamond point is used to scratch a polished surface and the depth of the scratch measured. Various devices of this kind are used in laboratories.

In testing a suspected glass imitation it should be remembered that while glass usually has a hardness of approximately 5½, some of the fused quartz glasses will have a superior hardness. In all tests made of gems, reliance should not be placed on one single determination, but should be supplemented with one or more additional examinations and the diagnosis made on this basis. A hasty or careless conclusion may later prove in error.

SPECIFIC GRAVITY

The comparison of the weight of a substance with an equal bulk of water is termed its specific gravity, or "gravity" for short, water being taken as a standard with a value of one. Although numerous of the gem minerals will vary slightly in gravity (see tables), this is generally not great enough to lead to incorrect conclusions; hence the specific gravity of a gem is a value clue to its identity.

There are a number of means by which the specific gravity of a gem (or rough fragment) can be determined. These involve (1) the use of accurate balances, and (2) heavy fluids of a known specific gravity. The stone must of course be removed from the mounting.

DIRECT WEIGHING—By the direct weighing method the stone is first weighed on the balances "in air." The gem is then weighed under water by suspending from the beam by a fine thread or wire. Obviously the gem will displace an amount of water equal to its bulk; hence, calculation of the gravity is a simple matter. Thus, if the gem weighs twelve carats "in air" and nine carats when suspended under water, the difference is three, and twelve divided by three gives four—which is the specific gravity of the gem. The larger the gem the smaller will be the factor of error. A stone weighing only one carat with an error of 1% in the readings, will yield an error of about 0.15 in gravity; hence accurate scales and handling are indicated in dealing with small gems.

For obtaining the gravity of very small gem stones or small fragments, the pycnometer can be employed, plus accurate analytical balances. The pycnometer is filled with water and weighed; the gem to be tested is then dropped into the glass stoppered container and again weighed, and the calculation made.

Various other types of balances are used for obtaining gravities, including the spring type known as the Jolly balance. Some of these are not suited for use with small gem stones, but are satisfactory where large masses are available, and where the factor of error is not so great. It is a good policy to form the habit of estimating the gravity of a gem by "hefting" it in the hand. A large stone of a heavy gem can thus be distinguished from one having a much lighter gravity, by the skilled hand. "Hefting" is, of course, of no value in the case of small gems or fragments.

HEAVY FLUIDS—Solutions made of various chemicals to yield fluids of a known gravity are of considerable value in rapidly determining the approximate specific gravity of a gem.

One of the most widely used fluids is Thoulet's Solution, prepared by saturating an

Braun Fluorolight used in demonstrating fluorescence of gems and minerals. Light weight, powerful and portable unit giving very low range A. U. ultra violet light. Useful as an aid in the determination of gem stones and minerals.

ounce or less of water with all the potassium iodide and red mercuric oxide that will dissolve. Several days should be given for complete saturation, and the clear liquid can be decanted into a small glass-stoppered, wide-mouthed bottle. When fully saturated Thoulet's Solution will have a specific gravity of 3.17 at ordinary room temperature.

The gem to be tested for gravity is simply dropped into the fluid. If it sinks the gravity of the stone will be greater than 3.17, and if it floats the gravity will be less than 3.17. This, of course, gives only an approximate gravity, but it will serve to distinguish between stones of some types. For example, topaz has a gravity greater than 3.17, while all types of quartz are less. Thus the so-called topaz of commerce, which is generally citrine or fused quartz, can easily be separated definitely. Thoulet's Solution is rather corrosive and should be kept from the fingers. The wide-mouthed glass-stoppered bottle will enable removal of the stones with tweezers. The gravity of the fluid should be checked at intervals by the use of some gem fragment having a known specific gravity.

Reference can be made to the table of specific gravity and other uses, for the heavy fluid will be noted. The fluid can be diluted with water to give any gravity less than 3.17, checking with fragments of known gravity.

There are other heavy fluids which can be used. Methylene iodide in benzol will give a gravity of 3.53, while a saturated aqueous solution of thallium malonate formate will give one of 4.38 gravity. Two indicators can be kept in the solutions, one heavier, which will always remain at the bottom, and the other slightly light, which should always float. In this manner a close check can be kept on the condition of the fluids. Thoulet's solution is perhaps the most satisfactory for general use. The fluids are, of course, limited in their use and should be looked upon as aids in checking other tests.

The various glasses which are used as imitation gem stones have a rather wide range of specific gravities, some being greater than 3.17, while others are less. Usually the special barium and lead glasses, which have a high index of refraction and are widely used, also have high specific gravities, but the hardness will always be low (about 5.5). This should be kept in mind in taking specific gravity readings, and judgment should not be passed until optical or hardness or other tests are made to verify the apparent findings. Some glasses have an index of refraction greater than that of quartz or topaz, and these fused substances can be made in almost any color. They may appear full of "life" and brilliance; hence, this should not be taken as a criterion of the real thing. Optical tests, made with the dichroscope, polariscope, refractometer, polarizing microscope and other optical instruments, constitute the most reliable means of differentiating the fused substances from the real gem minerals.

CRYSTAL STRUCTURE

If seen in the uncut and crystallized form, the gem mineral can be readily determined at sight by the lapidarist familiar with the forms in which these occur. If in a fragmentary or cut form the dichroscope or the polariscope will serve to separate those which belong to the isometric system from those of the other crystal systems. Thus a fragment of red garnet could quickly be separated from similar colored fragments of ruby or any other red stone which does not belong to the isometric system.

Crystallography is important in the study of gem stones, and every student should have at least an elementary knowledge of the subject to better understand the optical tests made in testing gems. All gems of the cubical system of crystallization are isotropic (show single refraction), and included in this group are the amorphous substances like glass. All other gems are anisotrophic (show double refraction), and these include those belonging to the hexagonal, tetragonal, orthorhombic, monoclinic and triclinic systems. Generally the hexagonal and tetragonal gems are *uniaxial*, and under the dichroscope show twin colors, termed dichroism and seen only in colored stones. Gems on the other crystal systems are *biaxial* and may show trichroism. All minerals of the cubical system never show twin colors under the dichroscope. This also applies to amorphous substances, except in instances where the substance may be under "strain," when pseudo colors may be noted by optical instruments.

FRACTURE—Some gem minerals fracture or break in a characteristic manner, which may be an aid in determination. Agate, for instance, shows an uneven fracture,

POLAROID — Hand Polariscope, used in the determination of gem stones. All amorphous substances (glass, etc., not under strain), and all isometric gem stones can be easily and quickly separated from those belonging to other crystal systems. See text for detailed description.

while other materials may show a conchoidal or other typical type of fracture.

CLEAVAGE—Other minerals tend to break along definite lines, which are termed *cleavage planes*. Quartz crystals do not exhibit this property, but topaz shows a very marked single cleavage plane which is parallel to the basal pinacoid and termed a basal cleavage. Topaz crystals are frequently seen with a single termination and on the opposite end will be noted a smooth flat basal cleavage. Diamond and fluorite tend toward an octahedral form of cleavage, and often a large cube of fluorite can be readily cleaved into a perfect octahedron.

Cleavage is of importance in the cutting of gem stones. In the case of topaz it is difficult to polish a large table exactly parallel with the basal cleavage, and for this reason the prominent facet is usually cut a few degrees off the plane of cleavage. In splitting a large

rough diamond into sizes suitable for cutting, cleavage is brought into play.

CHEMICAL COMPOSITION — Chemical composition of a gem offers a definite clue to its identity if material can be had for analysis. Blowpipe tests of a fragment may also give helpful data.

FLUORESCENCE—The reaction (change in color) of a mineral when exposed to ultra-violet light is termed fluorescence. This phenomenon is of some value in determining certain gems. For some unknown reason certain diamonds will fluoresce with considerable brilliance (blue) when exposed to ultra violet light in a dark room. In all probability the stones that react in this manner are those which come from some specific locality or mine. The X-rays also find use in the determination of some gems.

OPTICAL PHENOMENA

ASTERISM—Relatively few of the gem stones will show asterism or a "star," when cut en cabochon. The property of some gem stones to show a star is thought to be due to a reflection phenomenon, based on arrangement of the elemental atoms in the crystal structure. Asterism does not appear to be due to refraction.

Six-rayed stars are seen in sapphires, and the steep cabochon surface must be cut at exactly the right angles to the principal or "C" axis of the crystal, otherwise the star will be lacking or off center. Sapphire is hexagonal, and has three crystal axes, which lie in a plane at an angle of 90 degrees to "C" axis, and undoubtedly this is why we always find this gem with three intersecting lines, to form a six-rayed star. The star is not seen on facet cut gems, and the material must have a certain degree of opacity to present a star. It is not seen on every opaque sapphire. Only cutting will reveal the phenomenon. Pink-colored sapphires may also show asterism. These are termed star rubies.

Some garnets also show asterism, generally a four-rayed star, owing to the fact that this gem is cubical in crystallization and with all three axes of like optical properties. A few six-rayed stars have been noted in garnet, but these are accounted for on the basis of twinning crystal structure. The best star garnets appear to be found in Idaho, but good specimens have also been found in northeastern Oregon. In cutting for star garnet no special orientation is needed, as all sides of the crystal are alike from an optical standpoint.

Some massive quartz may also show asterism, but generally not so pronounced as that of sapphire and garnet. Recently some clever asterated doublets have appeared on the market under the trade name of "Satrolite." These are made by cementing a piece of blue-colored glass over a piece of quartz showing a star. By this means the six-rayed star in the quartz is brought out as a blue star, quite clearly, and similar to asterated sapphire. Amateur lapidarists of ordinary skill and experience can easily make doublets of this kind by following the technic given in the work under heading, "Making Doublets."

Asterism is to be found more rarely in spinel, topaz, emerald and a few other gems. Hamlin many years ago reported an asterated diamond in the Paris museum, but to date this has not been verified. In the Cleveland Museum of Natural History is a remarkable two-inch sphere of star garnet; as the ball is revolved large four-rayed stars will appear on numerous points of the sphere.

Hand dichroscope used for testing gem stones. The twin colors are seen through the eye-piece at top, stone is held at other end of instrument, and directed toward light. One of the most inexpensive and useful of all instruments for the determination of gems. See text for detailed description of use.

The cause of asterism is a matter of considerable technical interest and numerous theories have been advanced for the phenomenon. According to the recent work done by Dr. A. J. Wolcott of the Field Museum (Chicago), it is brought out that the rays of the star in all gems follow certain planes and directions of symmetry in the crystal. Along these planes of symmetry are minute microscopical crystals arranged in a regular manner. Or inclusions or markings of some kind are formed along regular areas in the crystal. Hence, when the stone (sapphire) is cut correctly in relation to the crystal axis the star will appear.

Hence, sapphire and quartz must be cut so the steep cabochon surface is in a direction perpendicular to the "C" axis, these two gems being hexagonal. In the case of garnet, orientation is not so important, for as many as twelve or more stars will appear on a single crystal, oriented at many points. Some rare specimens of garnet will show a six-rayed star, but most specimens show only four rays, as garnet is isometric. So far as can be learned the finest star garnets (admandite) have been found in the granites of western Idaho and northeastern Oregon. These localities have been referred to a number of times in back issues of THE MINERALOGIST Magazine.

EXAMINING FOR FLAWS

Flaws, inclusions and various crystallization and structural lines are sometimes an aid in making a determination. It may also be desirable to note flaws in appraising the value of a cut gem, or in noting these defects in an uncut specimen.

Flaws and structural defects can be more readily viewed if the cut gem or rough fragment be placed in various liquids, selecting one with a refractive index (R. I.) similar to the gem. Kerosene is frequently effective—a small amount placed in a white porcelain laboratory dish and the stone immersed and examined. Other suggested fluids include turpentine, oil of cedar, canada balsam, glycerine, castor oil, mineral oil and numerous others, which are listed with their R. I. in standard text books on optical mineralogy.

Assuming the liquid selected has a refractive index close to that of the gem mineral, the fragment or gem will become nearly invisible, especially if pale or colorless. Flaws, inclusions and other defects will stand out in glaring contrast, and thus enable easy detection. A low power, binocular type of microscope can be used in examining the stone in the liquid. Only enough liquid is required to cover or coat the gem. Water-worn pebbles of gem minerals can be better viewed internally if made wet with water, but the liquids suggested above will prove even more effective.

OPTICAL PROPERTIES

The optical properties of a gem are unquestionably the most reliable guide in determining its identity. This includes measuring the refractive indices, dichroism, and determining the crystal structure. Some of the optical properties of a gem stone (or a fragment of the rough material) can be easily determined with some simple instrument. Or at least the gem can be placed within a certain group, thus eliminating a long list of possibilities. Unfortunately the determination of some of the optical properties require the use of costly optical instruments, plus a technical knowledge of optics and theory of light. The expert, equipped with a polarizing microscope, and given the gem material in rough fragments, can easily determine with certainty any species of natural gem. The following optical properties can be determined by the aid of the polarizing microscope; usually only a part of these are needed to accurately identify the gem:

(1) Isotropic or anisotropic—This determines if the gem belongs to the isometric system, one of the other crystal systems, or is an amorphous substance.

(2) Uniaxial, positive or negative.

(3) Biaxial, positive or negative.

(4) Index of refraction.

(5) Axial angle and optical orientation.

Dr. Esper S. Larsen, in his work, "The Microscopic Determination of the Non-

ANALYZER

POLARIZER

POLAROID analyzer and polarizer. Inexpensive adaptors for converting an ordinary microscope into a polarizing instrument. By this aid gem minerals can be examined optically.

Opaque Minerals," lists in tables all the valuable optical properties of the gem minerals (not opaque). The student is referred to this work for detailed optical data.

It is not the purpose here to describe in detail the use of the polarizing microscope. This information is available in standard text books, and in the series of articles by Wayne A. Fox, in THE MINERALOGIST Magazine.

Optical instruments of the more simple type are described below. Most of these can be used effectively with only a fundamental knowledge of optics and crystallography.

DICHROSCOPE

The inexpensive hand dichroscope (see illustration), is one of the most useful and valuable instruments to aid in the determination of gem stones. No particular skill is required in the use of this instrument; simply the ability to compare colors and a knowledge of the gems which are known to show dichroism (twin colors in the instrument).

The dichroscope consists of a small prism cut from calcite (Iceland spar) mounted within the tube. The stone to be tested is held close to the small square aperture at one end of the tube and directed toward either daylight or an artificial source of light, and the gem viewed from the other end of the instrument. If the stone shows dichroism, two small squares of different colors will be noted. This is due to the ability of the Iceland spar prism to divide the ray of light passing through the gem into *two rays*—the ordinary and the extraordinary rays. Along each of the rays, as they travel along different paths within the gem, light is absorbed and reflected in varying amounts. Hence, the two rays emerge in different colors. In most instances these two rays cannot be detected with the naked eye, but in some gems they can be seen by the skilled eye. The calcite prism with its very strong double refracting powers clearly divides the two rays.

The use of the dichroscope is, of course, limited, but it is a very valuable instrument for its intended purpose. It is especially valuable in separating all gems which crystallize in the isometric system from those belonging to the other crystal systems. Colored glass is amorphous; hence these imitations will fail to show dichroism, except in some instances where the material may be under strain and a false or very feeble dichroism may be noted. Colorless gems will, of course, fail to show any color whatsoever. Any colored gem which is known to exhibit dichroism (or pleochoism), but fails to respond under the dichroscope, should be looked upon with considerable suspicion. For example, all colored tourmaline should show distinct and strong twin colors, and any stone that fails in this can be considered as some other gem (or imitation), without further examination.

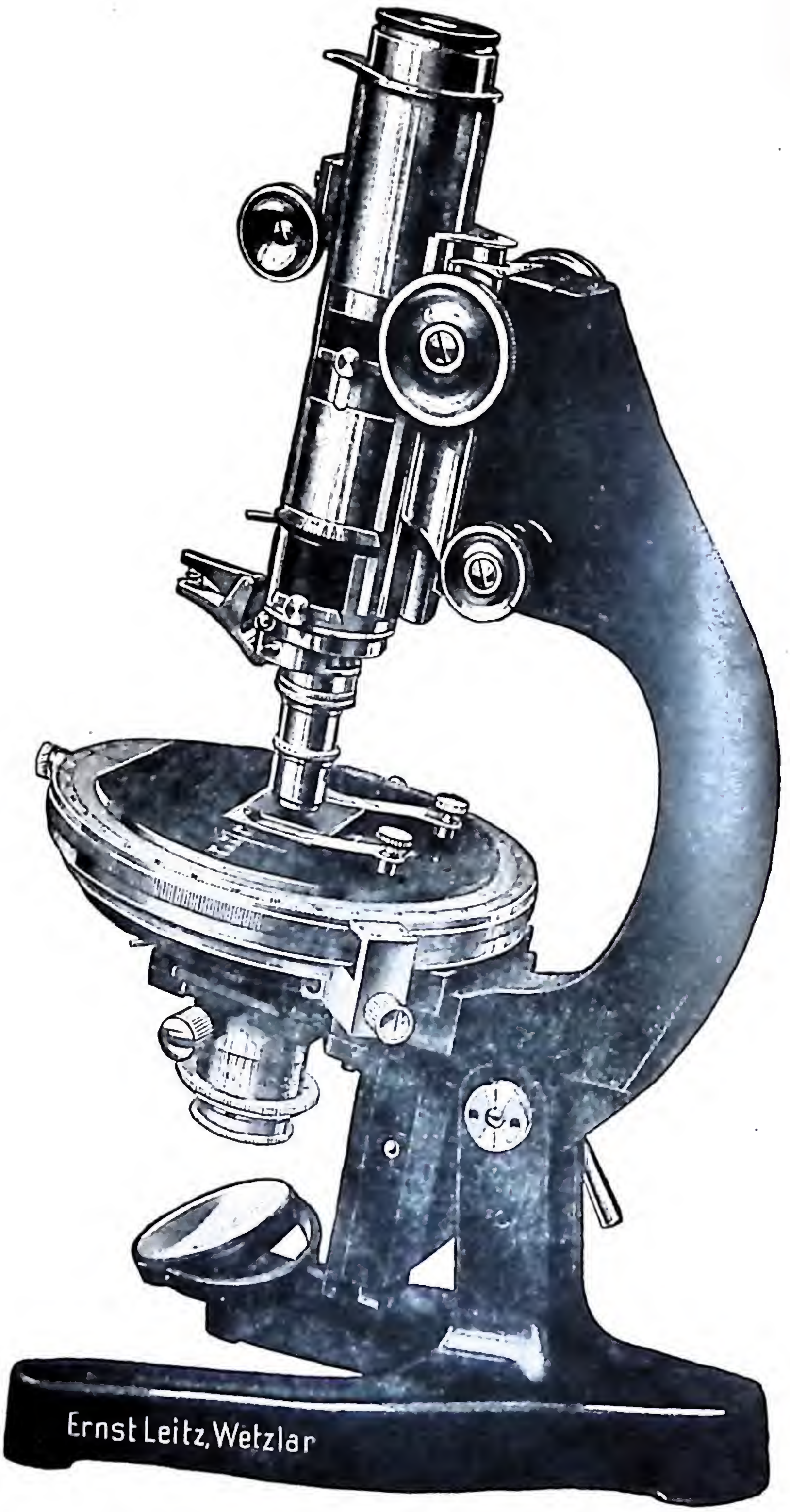
In some species of gems the twin colors seen will stand out in strong contrast and the stone is then said to show "strong dichroism;" in others the colors may differ only slightly and the gem "weak" or "feeble" dichroism. Emerald, for example, shows the phenomenon strongly with one square in the instrument of yellowish green and the other a distinct blue-green. As a rule the deeper the color in the gem the more noticeable the contrast of the twin colors in the instrument. In order to view a stone it must, of course, be a transparent one. Unmounted gems or a small fragment of uncut material is the most convenient to view with the dichroscope.

In using the dichroscope it must be remembered that the effect of dichroism can only be obtained when the crystal is viewed in certain relations to its crystal axis. Not knowing in what manner a gem stone has been oriented in relation to its crystal axis, it is always advisable to view the gem through different directions. If dichroism should appear and fails to show when the gem is viewed through the table, it should be turned and viewed through the girdle, or at angles in between the table and the girdle. By this means dichroism will be noted, if present, at some point. As the stone is held in the fingers and viewed in some one direction, the dichroscope should be rotated slowly between the fingers, as the twin colors may appear only when the instrument is rotated through the quarter part of a circle. A little practice with known gems or fragments of uncut material will soon enable you to gain the required skill of use. Below is given a partial list of gems which show dichroism.

Those showing strong dichroism include tourmaline, alexandrite, sapphire, emerald, ruby, kunzite and hiddenite. Dark colored stones of peridot show strong dichroism; the paler colored gems show less contrast in the twin colors. In zircon only the blue gems show a distinct dichroism; in other colors the gem is weakly dichrotic. All colored quartz like amethyst and citrine shows a distinct but not strong dichroism. All tourmaline regardless of color (except colorless) shows a very strong reaction. All colored beryl shows distinct twin colors, but the emerald green variety is, of course, the strongest. Reference to standard texts on gemmology will reveal other dichrotic gems.

Unfortunately the synthetic sapphires (including the red colors—ruby) will generally show twin colors, as well as the genuine; hence, this test is not reliable in separating the manufactured from the real. Synthetic sapphires are made in a wide variety of colors, and their determination is often a very difficult matter, so perfect has their manufacture been developed. In the past it was usually possible to note rounded or elongated air bubbles, with the aid of a low powered jeweler's loupe, but in recent years these imperfections have been eliminated, which complicates identification. It is not possible to focus down into a gem stone with a high powered microscope, especially if the stone is deeply colored; hence the attempt to use a high magnification to detect fusion structure is beset with difficulties. Some synthetic sapphires are so well made that even experts, with complete laboratory equipment at hand, may hesitate in making a definite statement, without first giving the gem a long and careful scrutiny. So closely does synthetic sapphire resemble the real gem that the usual tests of hardness, specific gravity, chemical composition, and color are worthless. The fused boules even have a crystalline structure

(Cont. on Page 62)



Polarizing microscope, with built-in revolving mechanical stage. Used for determining the optical properties of gem minerals. (Illustration courtesy Ernest Leitz Company.)

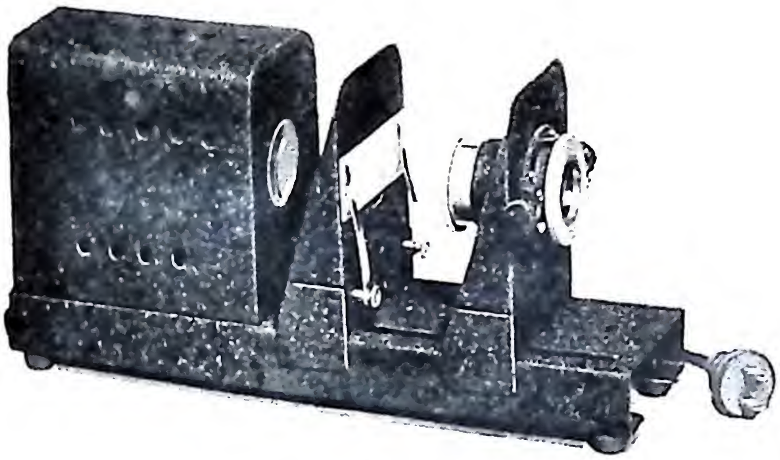
which adds to the difficulties. As a result reliance must be placed solely on the ability to note a curved structure in the gem, the result of fusion lines, formed when the gem was built up in the flame of the oxygen blowpipe. So fine are these structural lines that their determination is difficult. The natural gem shows the straight lines of hexagonal crystallization.

POLARISCOPE

The inexpensive hand polariscope (Polaroid equipped) is a very handy little instrument for the purpose of testing gem stones. The polariscope illustrated here consists simply of two disks of Polaroid, mounted at each end of the short tube. The lower disk is stationary, while the upper (analyzer) can be rotated. The stone or fragment of mineral to be tested is merely dropped into the instrument and viewed by holding toward the light.

The principal use of this instrument is the separation of all isotropic substances (not under "strain") from anisotropic solids. The gem or fragment to be tested must, of course, be transparent to permit the free passage of light. Since all gem stones crystallizing in the cubical (isometric) system are isotropic, the hand polariscope will readily separate these from the gems crystallizing in any other crystal system. All fused glass imitations are amorphous and these will also act in a manner the same as the isotropic gems. As an example, diamond always crystallizes in the isometric system, while zircon is tetragonal; hence the polariscope would instantly separate a colorless zircon from a diamond. Likewise, any colorless or colored glass imitation could readily be detected without further examination. Or a pink or red colored garnet sold or represented as tourmaline could easily be referred to the isometric system and definitely classed as some substance other than tourmaline.

The use of the hand polariscope is a simple matter. The gem or mineral fragment to be tested is simply dropped into the opening of the instrument and held toward the light. The upper disk is then rotated until only a very faint purple color is seen. In this position the "Nicols" are said to be "crossed." Theoretically in this position the field should be totally dark and no light whatever passed. However, the instrument is not 100 per cent perfect and permits a small amount of the purple rays to pass. In very costly microscopes and polariscopes, the Nicol prisms are made of Iceland spar and even in these instruments a small amount of light does get past. When the stone is viewed in this "crossed" position of the analyzer, and the stone remains dark and scarcely visible, it is either a fused glass or it belongs to the isometric crystal system. On the other hand, all other gems crystallizing in one of the other crystal systems would permit light to pass through the stone, to render it clearly visible. Practice can be made with known substances to observe the manner in which the instrument is used. A fused glass might be under a "strain" and thus permit a small amount of light to pass, but as a rule it will not be as fully "illuminated" as a natural stone. It is advisable to examine the gem or fragment by turning it in different positions and making sure that what appears to be light passing through is not a reflection of light caught



POLAROID Projector. Thin sections, slides, crystals, mineral cleavages, gem stones, and liquids can be projected on screen under ordinary or polarized light. The phenomenon of polarized light can be demonstrated to a large audience by the aid of this light weight, compact and inexpensive projector. The analyzer can be rotated same as in miscrocope. Beautiful and spectacular interference colors can be projected on screen.

from the outside by one of the facets.

The theory of the operation of the polariscope is simple. If the upper disk (analyzer) of Polaroid were removed, the light passing through the other disk would be only partially polarized. About half the light is excluded when only one disk is used. The disks of Polaroid are made in such a manner that light vibrating in *only one plane* can pass. Thus, when the analyzer disk is rotated in such a position as to coincide with the lower disk (the polarizer), half the light will continue to pass through the instrument. On the other hand, if the analyzer is rotated through ninety degrees (one-quarter turn) the disks are then said to be "crossed" and theoretically no light can pass through.

Amorphous substances (like glass) lacking in crystal structure have no effect upon the passage of light between the crossed disks. The same is true of all gems and minerals which crystallize in the isometric system. All gems crystallizing in any of the other systems have the property of rotating the light passing between the disks in such a manner that it will pass through the gem and thus the stone appears as being "visible." This may sound complicated, but the use of the polariscope is quite simple, with a little study of the manner in which known substances act. Like in the use of the dichroscope, the stone should be tested in various positions to enable examination in the various optic axis planes. Some gems, like tourmaline, are nearly opaque when viewed directly down on the "optic axis." On the other hand, all amorphous substances and isometric gems are opaque between the crossed disks, when in any position of orientation of the crystal axis.

Viewed under the hand polariscope, gems which are dichroic will be seen to change in color as the analyzer is rotated. The polariscope, however, does not show the twin colors separated as clearly as does the dichroscope. The two instruments are wholly different in operation. The synthetic sapphire type of gem, being of a crystalline structure, will act like any other hexagonal substance, as referred to under the dichroscope. The synthetic spinel type of fused material, which is in wide use, will appear as an insotropic substance and will remain dark under the crossed disks.

The little hand polariscope can be used to see the beautiful interference colors in various minerals. A thin piece of selenite or a thin cleavage of mica will show marvelously beautiful colors of this kind. The various "orders" of colors can be easily demonstrated by folding various thicknesses of ordinary colorless cellophane and viewing through the polariscope, with the disk in various positions. Very thin cleavages of mica built up into "steps" and passed through the instrument will show the different intensities of interference colors. Obviously the polariscope can also be used to separate all transparent isometric minerals from those of the other crystal systems, and is thus a useful instrument in mineral determinations. Suitable size and thickness fragments or sections cut to the proper thickness can be tested as easily as a gem stone. Like the dichroscope, the polariscope is limited in its use; but is a valuable and satisfactory instrument for its intended purposes.

A special hand polariscope (Polaroid) for testing gem stones has been designed by THE MINERALOGIST Laboratory. By the aid of this instrument numerous gem stones can be separated into their respective classes. The instrument is fitted with a special holder for the gem stone. A rotating stage and a low power lens can be readily adapted to the instrument.

REFRACTOMETER

The refractive index of a gem stone is an important and valuable clue to its identity, and when a correct and accurate figure is obtained, identification is made certain. There are various means by which the refractive index (R. I.) of a gem or mineral may be obtained. One involves the use of an optical instrument known as the refractometer.

With this instrument a direct reading of the R. I. of a gem stone may be obtained. A polished surface, usually the table of the gem, is placed in contact with the glass hemisphere of the instrument and the reading taken. Fairly accurate results can be attained with the refractometer, but its range of use is limited to the gem with the medium and lower refractive indices. Gems like diamond, zircon, garnet and some others are beyond the range of the refractometer. Its upper limit of R. I. readings is generally from 1.70 to 1.90. The refractometer is not an inexpensive instrument. They are generally priced from about $50.00 upwards. They are, however, valuable in the field of gemmology.

MICROSCOPE—HAND LENS

HAND LENSES having magnifications of from eight to ten are useful, especially in the hands of experts. The "amateur" will derive little benefit in making a determination solely by the aid of a simple magnifying lens. The eye "loupes" used by jewelers have a magnification of approximately eight, and are useful for detecting flaws in gems, noting the manner in which the gem is cut, detecting carbon inclusions in diamond and similar physical examinations.

The ORDINARY MICROSCOPE is limited in its use, but the low magnifications find limited applications. The difficulty in using the high power is the inability to focus down into the body of the stone, and in the case of a thick or deeply colored gem it is impossible to get enough light through the gem to render clear visibility. High powers on a microscope have a very short "working distance," and it is obviously impossible to get focus down into the gem.

With the recent introduction of the inexpensive Polaroid disks, it is possible to easily convert the ordinary biological microscope into a polarizing instrument, this making it much more useful for examining the optical properties of gem stones. In making this conversion, one disk (polarizer) is slipped into the slot on the condenser, while the other disk rests on the eyepiece, in the form of a rotating analyzer. With this equipment the same work can be done as with the hand polariscope, but with the added advantage of having magnification available.

BINOCULAR MAGNIFIERS of low power are very useful in making a critical examination of a gem stone, and to aid in detecting various flaws, imperfections, cutting and various other features. Generally low powers from 10X to 40X are used with this instrument. The binocular type of microscope has the advantage in that it gives a three dimension field of view, and makes it possible to focus accurately on an area within the stone. These instruments have a rather long "working range;" hence thick stones can be clearly viewed internally, provided they are not too deeply colored or opaque.

Carbon and other inclusions in diamonds can be easily and clearly seen in all parts of the stone, inclusions which are wholly invisible by the naked eye. The binocular type of instrument is finding wide use for the commercial examination of diamonds. In some cases the fusion markings and other telltale imperfections in synthetic sapphire can be seen with the aid of this instrument. The binocular magnifier is very valuable for the examination of very minute crystallization, ore examinations and various other uses in the field of mineralogy.

POLARIZING MICROSCOPE

The polarizing or petrographical microscope is an entirely different instrument from the ordinary biological or bacteriological instrument. The polarizing instrument is equipped to give not only various magnifications, but to enable the examination of various substances under polarized light, and thus gain a knowledge of the optical properties of the material. This is important in learning the identity of a gem mineral.

Like other microscopes, large and deeply colored gems cannot be satisfactorily examined under the polarizing instrument. It is generally customary to work with either very small crushed fragments or a thin cut section. With this instrument it is possible to determine the crystal system to which the substance belongs, and to get an accurate index of refraction.

Usually only very small fragments are needed. Those approximately of 200 mesh are sufficiently large. Various immersion fluids are used, in which fragments are placed. The refractive index of the liquid being known, it is possible to thus get a quite accurate reading on the fragments, out to the third and fourth decimal place. In order to use the polarizing microscope intelligently, it is necessary to have a knowledge of the optics of light and the properties of the various crystals, plus experience in the observation of the various phenomena seen.

Unlike the ordinary microscope, the polarizing instrument is fitted with a revolving stage which permits the material under examination to be rotated between the polarizing prisms mounted below and above. This enables the more ready determination of some of the optical properties of the substance. For detailed use of this instrument the reader is referred to text books on the subject. In the hands of the expert the polarizing microscope is an invaluable instrument and enables the operator to definitely determine *any* non-opaque mineral with accuracy. Owing to the fact that these instruments are fitted with costly Iceland spar prisms, they are expensive. The lower priced instruments range from approximately $350.00 to $400.00, while the more fully equipped microscopes will range upwards to nearly $1,000.00.

Low priced instruments suitable for the "amateur" are not available at present, but with the recent perfection of the new polarizing substance, "Polaroid," it is very likely that an instrument of this kind will appear on the market. With the elimination of the costly prism of Iceland spar, the reduction in cost would be at least $100.00, all other things being equal. There is a distinct need and demand for an instrument of this kind and the prediction is here made that a microscope of this kind will be available in the near future.

News of the Societies

Rawlins, Wyoming, is going lapidary minded, reports W. A. Brox, the pioneer gem cutter. Over a dozen collectors of Rawlins have set up lapidary equipment and are taking first-hand instructions from Mr. and Mrs. Brox.

* * *

Among the twenty or more excellent displays of collections at the meeting of the *Northwest Federation* at Olympia, Washington, the semi-precious mineral collections of Robert N. Ross, Seattle, and Mr. and Mrs. A. A. Dixon of Portland were outstanding. The collection of local fossils (no pun intended) made by Ray Gruhlke gave a good indication of the material available in the Olympia area.

The next big convention in the Pacific Northwest will be held at Portland in October, 1938. The officers of the Federation have set a goal of a registration of 1,000 delegates and members. It can be done. Plan now to attend.

* * *

Dr. Groesbeck of Porterville, California, gave an illustrated lecture on "Rare Gems" at the February meeting of the *Kern County Mineral Society*. During the year 1937 membership in the organization was doubled.

* * *

Stephen Varni, New York City gem expert, gave an illustrated lecture on "Gems and Gem Cutting" at a meeting of the *Boston Mineral Club*. Lantern slides were used to show lapidary equipment in operation.

* * *

Professor Wayne Fox appeared at the February 9 meeting of the *Northern California Mineral Society*. His lecture and demonstration on the use of the polarizing microscope in mineralogy was very well received by more than 100 members and visitors.

* * *

J. Lewis Renton, President of The Mineralogist Publishing Company, is spending several weeks on a "field trip" to the Hawaiian Islands. Mr. Renton is a former resident of the Islands.

* * *

Dr. Eugene Payne, Windsor, Colorado, spoke on "Adventures of a Gem Collector in South America" at the February meeting of the *Colorado Mineral Society*. Dr. Payne is a well-known Colorado surgeon. He recently spent four months in South America visiting gem localities. His illustrated program brought out a record-breaking number of members and visitors.

* * *

Dr. P. Victor Peterson lectured on "The Chemistry of Minerals" at the March meeting of the *San Jose Mineral Society*.

* * *

At the March 17 meeting of the *Stockton Mineral Society*, in honor of "St. Pat," the Irish collector, all members brought green specimens to display. The combined exhibit proved of considerable interest.

* * *

Walter Sutter, Tacoma, Washington, appeared before a recent meeting of the *Seattle Gem Collectors Club* to deliver one of his refreshing illustrated lectures. Mr. Sutter has that rare ability of not only presenting an informative program, but at the same time injecting an abundance of wit and humor. He is the Tacoma City Engineer. His hobby is "rocks."

CHICAGO MEETING

At the annual meeting of the *Marquette Geologists Association*, H. C. Walther was elected President W. E. Menzel, Vice-President, and Secretary, George J. Huss, 1718 S. Jefferson Street, Chicago.

The regular meetings of the Association are held on the first Saturday of each month, at the Marquette Institute, 155 North Clark Street, Chicago. Study meetings and field trips are also sponsored. Regular meetings are open to visitors. You are invited to attend.

BOSTON CLUB

The *Boston Mineral Club* is one of the several organizations enjoying a very rapid growth in membership. One of the "secrets" of the popularity of this group is their ability to secure excellent programs to present to the membership and visitors.

The Club meets on the first Tuesday of each month, at the New England Museum of Natural History, 234 Berkeley Street, Boston. Visitors are always welcome, reports Secretary Mrs. Charles Worley.

GEORGIA SOCIETY

At the annual meeting of the *Georgia Mineral Society* the following officers were elected to serve for the year 1938 President, S. P. Cronheim; Vice-President, J. G. Lester; Treasurer, H. C. Uhl; Secretary, John H. Olden, 54 Brighton Road, N. W., Atlanta, Georgia.

At the January meeting Dr. Walter B. Jones, State Geologist of Alabama, addressed the Society on "Some Interesting Mineral Localities of the East" Dr. Jones also presented a collection of minerals to the Society.

STOCKTON CLUB

In response to a growing local need the *Stockton Mineral and Gem Club* has been founded at Stockton, California, according to M. D. Taylor, President. Other officers elected include Mrs. Ethel Taylor, Vice President, and Mrs. Luella Brittsan, Secretary. Professor J. H Jonte, College of the Pacific, will act as educational adviser.

THE MINERALOGIST Magazine was designated to act as the official publication, and readers of this journal residing in the Stockton district are invited to meet with the Club.

PACIFIC MINERAL SOCIETY

With twenty-five persons attending at the first meeting, the *Pacific Mineral and Gem Society*, was founded on February 4 at Los Angeles. Regular meetings will be held on the first Thursday of each month at the Manual Arts Night School. The new organization has been elected for membership in the California Federation of Mineral Societies.

Laura Gutman, 975 Ingraham Street, Los Angeles, is Secretary, and Victor Arciniega, President. Dues in the Society are nominal.

LAPIDARY EQUIPMENT MANUFACTURERS

The information given in this chapter, pertinent to the equipment, has been supplied by or taken from the literature of the manufacturer. The writers do not recommend any particular make of equipment, but the machines illustrated and described here have been on the market and in use for a number of years and are known to be reliable.

The purpose of this presentation is to better enable the reader who desires to purchase ready to use equipment, to select that which appears most suitable for the intended purpose in mind. The writers are not engaged in the manufacture of lapidary equipment.

READY FOR USE

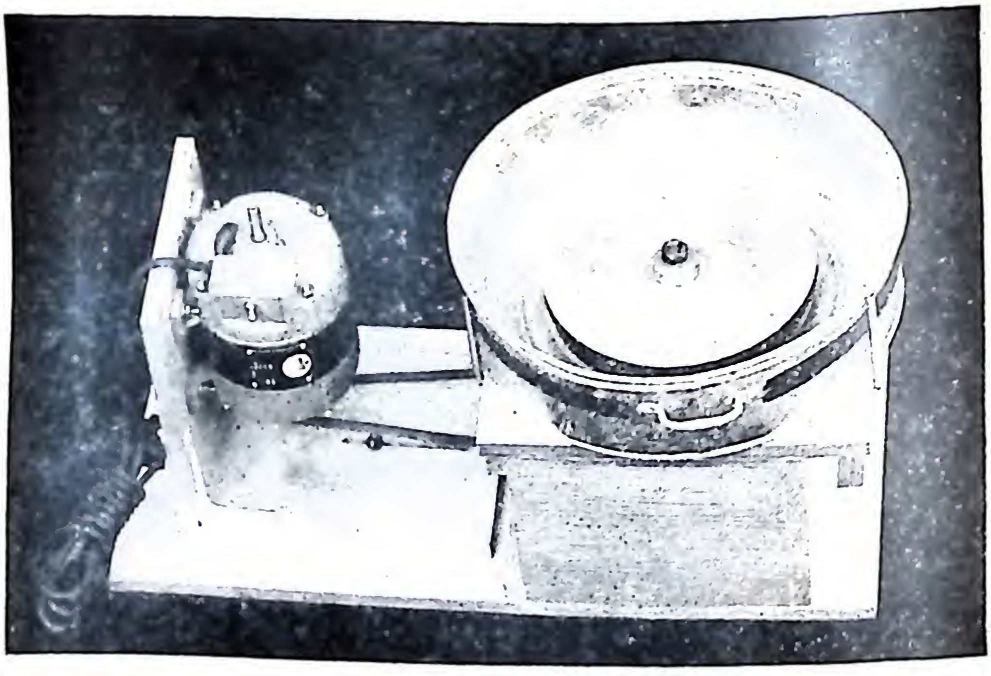
The units shown here are ready to use and complete in most instances. Running water connections are desirable for some units, while for others an electric outlet is all that is required. The units shown here are freely portable and can be set up wherever electric power is available.

Obviously a small compact unit, where change of accessories is required for each operation, will not turn out work as fast as large commercial equipment. This however should not be a disadvantage for after all the "amateur" or the home lapidarist is not concerned with speed of production. Some of the more specialized units shown here would prove useful in commercial shops.

THE PETHERICK LAP

The Petherick lap, is a rigid horizontal running unit, 30 inches long, 14 inches wide, and 14 inches high, weighing 60 pounds, including motor. The spindle is mounted on SKF bearings. The laps used are of standard 8 and 10 inch size.

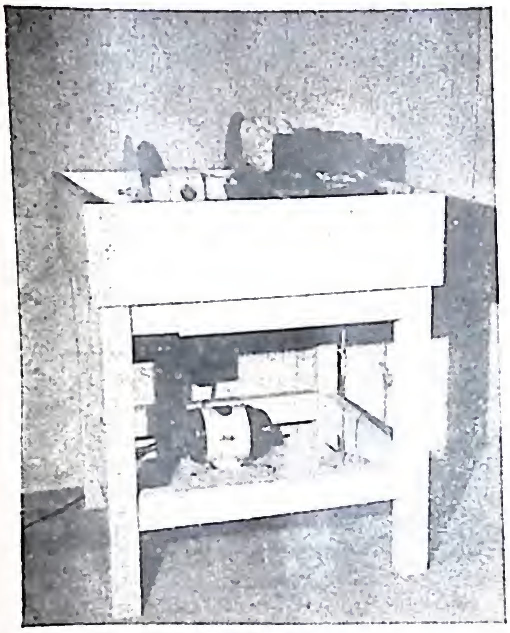
The one-quarter horsepower electric motor is of the ball bearing type and is mounted in a vertical position, using



THE PETHERICK LAP
Horizontal running lap sold by C. W. Marwedel Company of San Francisco. Grinding laps are readily interchangeable. Felt polishing laps can be adapted. This unit is intended primarily for finishing large flat surfaces on specimens.

a V-belt. The motor has a speed of 1,750 R.P.M. and by the use of different size pulleys, lap speeds of from 450 R.P.M. to 3,500 R.P.M. can be obtained.

Various metal laps can be used with this unit, including the sheet metal laps, which can be placed over the "master" lap. The Petherick Lap is readily portable and is sold by the C. W. Marwedel Company, 1235 Mission Street, San Francisco, California.



Complete sawing unit for diamond or mud sawing, Delta equipped and manufactured by Vreeland Company. Note carriage holder for work on right, smaller "resaws" on left. Three speeds are given by motor pulleys, 245 - 392, and 540 R.P.M. to accommodate various size saws.

CLINEFELTER & LARSON COMPANY

Clinefelter and Larson Company of Oswego, Oregon, manufacture a number of lapidary units, as well as various accessory tools and equipment.

The variable speed horizontal running unit manufactured by this firm is intended for both facet cutting and specimen grinding and finishing.

The Clinefelter mechanical facet cutting head shown here is widely used by both commercial and "amateur" facet cutters.

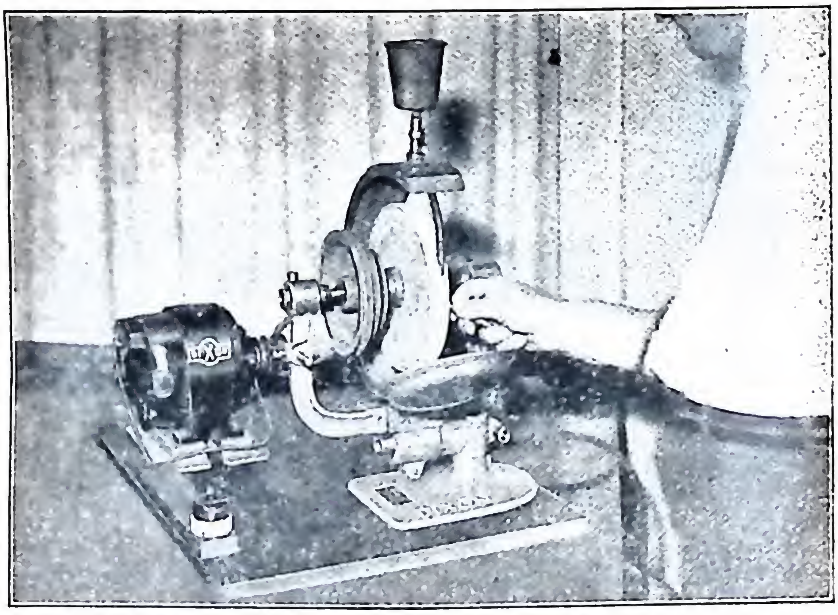
DIXON LAPIDARY MACHINES

The Dixon Lapidary Machines, shown illustrated here, are conspicuous for their quiet operation, insured chiefly by the use of cone bearings running in lignumvitae. They can be used without annoyance of sound or vibration in the home, classroom or shop.

Correct speeds for lapidary work on either machine can be obtained by merely shifting the V-belt on the motor pulley and on the three-step arbor pulley. Three speeds are thus provided. Full commercial size grinding wheels of ten inches can be used on the No. 1 machine.

Machine No. 1 is intended for cabochon work by changing the various tools on the arbor. Grinding wheels, saws, sanders, and polishing buffs can be used on this self-contained unit.

Machine No. 2 is principally for facet cutting and is shown illustrated with the *Jamb Peg* for holding the dop at proper angle and position. Both machines are freely portable and operated by one-quarter horsepower electric motors.



Dixon Company Machine No. 1. Grinding operation on silicon carbide wheels. Drip method of applying water to wheel.

BOOKS FOR THE GEM CUTTER

(1) "Quartz Family Minerals"—by Dake, Wilson and Fleener. The only complete work in the English language on the many varieties of agate and quartz. Written in non-technical style and invaluable to the gem stone cutter. Price, $2.50.

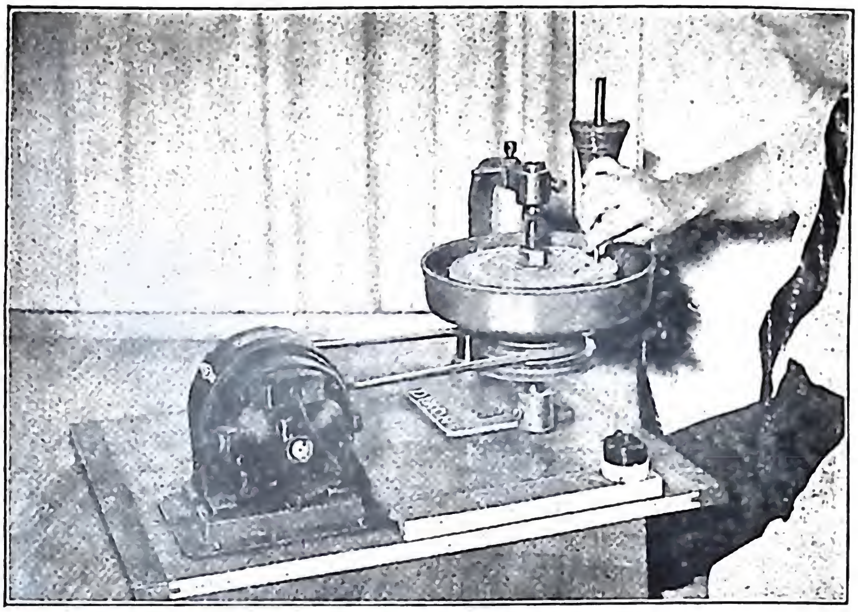
(2) "Getting Acquainted With Minerals" —by English. A general work on mineralogy, describing all the more common varieties. Suitable for the mineral collector, student, and lapidarist. Price, $2.50.

(3) "Handbook for the Craftsman"—by Baxter. A well illustrated, descriptive work on the mounting of gem stones, and art metal work. Detailed instructions are given to enable the lapidarist to mount his own gems. Price, $2.50.

(4) "Gems and Gem Minerals"—by Kraus and Holden. A general work on gemmology, and suitable for the gem cutter.

(5) "Legends of Gems"—by Thomson. A descriptive work pertinent to the fascinating and romantic history of gems. Price, $1.15.

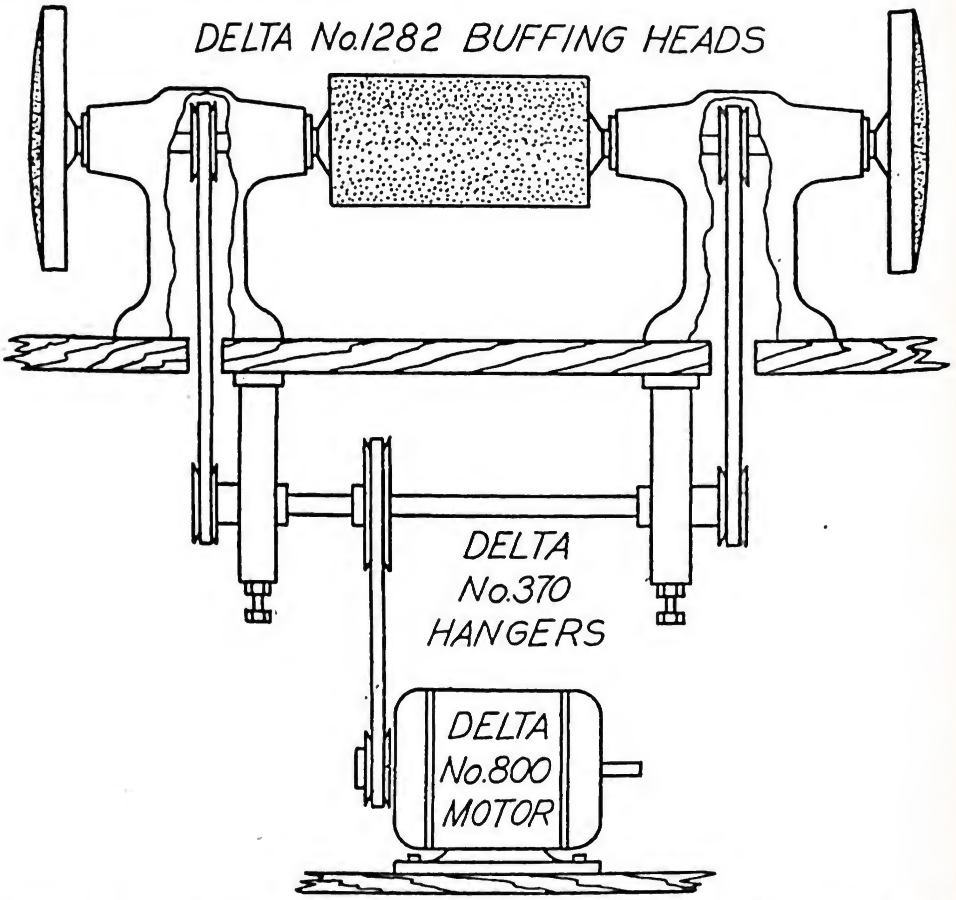
(6) "Abrasives for the Lapidary"—Free booklet by Norton Company, Worcester, Mass., or Norton Company agents.



Dixon Company Lapidary Machine No. 2, showing horizontal running lap used for facet cutting. This unit is also valuable for grinding thin sections, transparencies, and flat surfaces on specimens. Jamb Peg for facet cutting is shown in use. The Dixon Lapidary Units are freely portable, self-contained, and ready to use.

VREELAND LAPIDARY EQUIPMENT

The Vreeland Lapidary Machinery Company of Portland, Oregon is engaged in the manufacture of a complete line of equipment and accessories for both the commercial and "amateur" gem stones cutter.



Details of Combination Drum and Vertical Sanders Unit built by the Vreeland Lapidary Manufacturing Company. Variable speeds can be had with this unit, intended for the sanding of both cabochon stones and large flat or curved surfaces.

TABLE OF HARDNESS AND SPECIFIC GRAVITY

Gem.	*S. G.*	*H.*
Alexandrite	3.64	8.5
Almandite	3.68—4.33	7 —7.5
Amber	1.05—1.10	2 —2.5
Amazon Stone	2.54—2.57	6 —6.5
Andalusite	3.1 —3.2	7 —7.5
Apatite	3.15—3.27	4 —5
Azurite	3.77—3.83	3.5—4
Benitoite	3.64—3.65	6 —6.5
Beryl	2.63—2.91	7.5—8
Calcite	2.69—2.82	3
Cassiterite	6.8 —7.1	6 —7
Chalcedony	2.55—2.63	6 —7
Chiastolite	3.1 —3.2	7 —7.5
Chloropal	1.82—	2.5—4.5
Chrysolite	3.3 —3.5	6.5—7
Chrysoberyl	3.5 —3.84	8.5—
Chrysocolla	2.4 —2.41	2 —4
Cinnabar	8.0 —8.2	2 —2.5
Corundum	3.95—4.10	9 —
Diamond	3.15—3.52	10 —
Dumortierite	3.26—3.36	7 —
Epidote	3.06—3.5	6 —7
Fluorite	2.97—3.25	4 —
Garnet Group	3.15—4.3	6.5—7.5
Glass (fused)		5.5—
Grossularite	3.4 —3.6	6.5—7
Gypsum	2.3 —2.45	3 —4
Hematite	4.9 —5.3	5 —6.5

Gem.	*S. G.*	*H.*
Hiddenite	3.1 —3.2	6 —7
Jadeite	3.3 —3.5	6 —7
Kunzite	3.1 —3.2	6 —7
Labradorite	2.68—2.72	5 —6
Lapis Lazuli	2.38—2.45	5 —5.5
Malachite	3.9 —4.03	3.5—4
Marcasite	4.6 —4.9	6 —6.5
Moonstone	2.5 —2.6	6 —6.5
Nephrite	2.69—3.1	6 —6.5
Obsidian		5.5—
Olivine	3.3 —3.5	6.5—7
Opal	1.9 —2.3	5.5—6.5
Peridot	3.3 —3.5	6.5—7
Phenacite	2.94—3.04	7.5—8
Pollucite	2.86—2.9	6.5—
Prehnite	2.8 —2.9	6 —6.5
Pyrite	4.95—5.16	6 —6.5
Pyrope	3.5 —3.8	7 —7.5
Quartz	2.59—2.66	7 —
Rhodochrosite	3.3 —3.76	3.5—4.5
Rhodolite	3.83—	7 —7.5
Rhodonite	3.4 —3.68	5.5—6.5
Ruby Spinel	3.52—3.71	8 —
Sapphire	3.95—4.10	9 —
Smithsonite	4.30—4.45	4.5—5
Sphalerite	3.9 —4.1	3.5—4
Spinel	3.5 —4.1	8 —
Sunstone	2.6 —2.7	6 —6.5
Thomsonite	2.19—2.4	5 —5.5
Topaz	3.4 —3.65	8 —
Tourmaline	2.9 —3.2	7 —7.5
Turquoise	2.6 —2.88	5 —6
Variscite	2.47—2.54	5 —
Vesuvianite	3.35—3.45	6.5—
Zircon	4.02—4.86	7.5—
Zoisite	3.25—3.36	6 —6.5

SELECTING GRINDING WHEELS

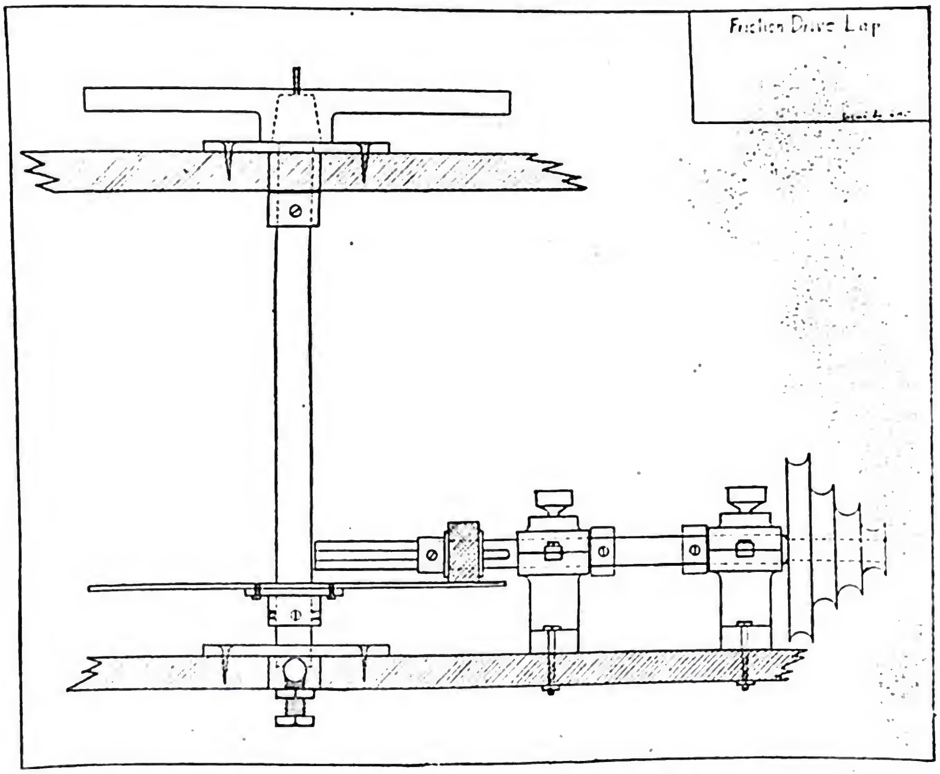
The selection of the proper grit and a suitable bonding of the silicon carbide wheels used for gem stone cutting is of importance in order to get the greatest efficiency and economy from the tool. While perhaps the "amateur" may not be particularly interested in speed and economy of the grinding operation, it is of considerable importance to the commercial establishment, or the users of large quantities of grinding wheels.

Silicon carbide grinding wheels are manufactured in various types of bonding, carrying different size grits. These are designated by the use of numbers and letters, different manufacturers using various systems of designation. A "soft bond" wheel permits the abrasive grains to be lost faster from the surface of the wheel, thus presenting new and sharp cutting edges at a faster rate. On the other hand the harder bonds tend to cling to the abrasive grains, holding them longer regardless of sharpness, hence a type of wheel suitable for grinding steel would be wholly unfit for gem stone grinding even though the grit size may be identical. In general, softer bonded wheels are used for the harder gems and vice versa. As a matter of practice some gem cutters and even commercial establishments use the same grade of wheel for practically all work. However, if a great deal of special work is to be done, it would be economy to select the proper grade and bond wheel. It must be remembered that too hard a bonding may "glaze" and refuse to cut, developing heat from friction.

For illustrative purposes the wheel markings used on *Crystolon* grinding wheels (Norton Company) are given below.

For preliminary rough grinding and shaping of gem material the following wheels are recommended:

37-80-I	Very Fast
37-80-J	Fast
37-80-K	Medium
37-80-L	Slow
37-80-M	Very Slow



Horizontal running lap unit manufactured by Clinefelter and Larson Company. The unit is available complete with motor and ready to use. The variable speeds enable numerous operations to be carried out.

In the above table the figures "37" pertains to the code marks used to designate silicon carbide as the abrasive used in the wheel. The second set of figures "80" designate the size of the grit. The regular vitrified bonded wheels are generally used in gem cutting except for special purposes when some other bonding may be most suitable.

Starting with the "I" bond wheel, this is a very "soft" wheel and will give *great speed* in cutting any hard gem material other than diamond. The "I" wheel cuts very fast as the periphery of the wheel will slough away rapidly thus presenting new and sharp grits frequently. The harder bonds will slough away slower and hence cut with less speed, but on the other hand will give greater wheel economy. By selecting a bond that will cut reasonably fast, and yet not show too much wheel wear the greatest economy will be had.

In general the "L" and "M" bonds are used for gems with a hardness of seven or less, and for harder stones the "J" and "K" bonds will be found most suitable. Good all around cutting can be had from the "L" and "M" bonds, and this type is generally use by the amateur. The commercial establishment handling large quantities of stones may use several different bondings. With silicon carbide wheels the speed of cutting and wheel economy is in the hands of the operator.

Soft gems like opal, turquoise, and malachite will show very little wheel wear, even after prolonged use, on the other hand hard and tough gems like agate will show much more wear on any type of wheel.

Two grinding wheels are generally used in small cutting shops, one mounted on each end of the arbor. For roughing out the No. 60, No. 80, No. 100 and No. 120 grits are generally used, for all around purposes the No. 100 is suggested. For the "second cutting" and shaping, finer grit wheels are used as indicated below, these are also useful to carry out the rough grinding on valuable gems like opal.

37-180-I .... Very Fast
37-180-J .... Fast
37-180-K .... Medium
37-180-L .... Slow
37-180-M .... Very Slow

The grit size given above is No. 180, but a finer grit like No. 240 can be substituted if so desired. The modern silicon carbide grinding wheel is perhaps the finest and most efficient tool available for lapidary work and to get best results it is only necessary to keep in mind the above facts. Complaints of excessive wheel wear or lack of speed in cutting can be accounted for by the use of improper wheel for the material at hand, or abuse of the wheel.

MINERAL SOCIETIES— GEM CLUBS

There are some seventy or more mineral societies, gem clubs, and similar earth science organizations scattered in various parts of the country. These organizations present frequent programs of an educational nature and pertinent to gem or gem cutting studies. As a rule the membership fee charged is only a nominal one and you can derive considerable benefit from membership in an organization of this kind.

THE JOHNS GEM CUTTER

The Johns Gem Cutter is a popular priced, portable, self-contained unit, built sturdily of metal, with precision methods, and complete with all accessories and abrasives for cabochon cutting, flat surfaces and sawing small specimens. It is fitted with a calibrated faceting attachment capable of giving 192 different facet-angles.

The water reservoir and splash pan system permits the machine to be set on any table and operated without damage to the surroundings. The Johns Gem Cutter is light in weight and freely portable, and is intended for use mainly in the home and the school room. The machine comes complete, ready to use by plugging into any electrical socket.

THE JOHNS GEM CUTTER

Complete unit intended for both cabochon and facet cutting. Light in weight, freely portable, and can be operated by a small electric motor. The unit is complete and ready to use.

QUICK TEMPORARY POLISH

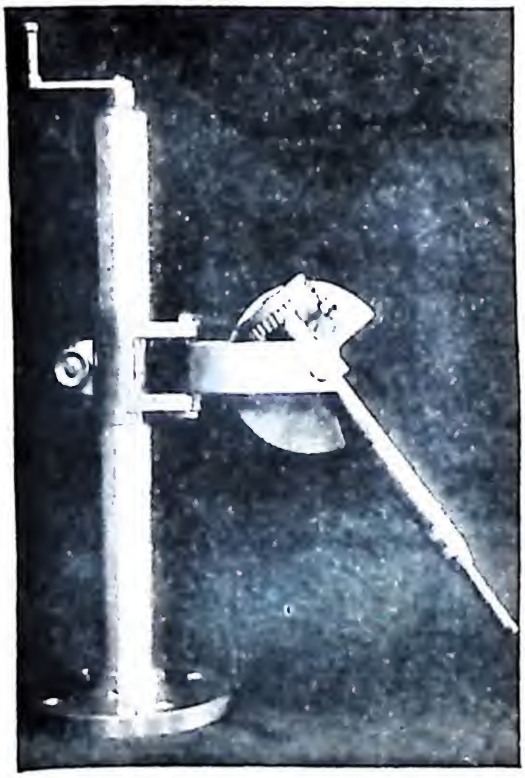
It may at times be desirable to place a temporary "shine" or polish upon a specimen, to indicate how same will appear when finished. It is customary to wet the surface of a specimen after sawing to bring out the details hidden by the rough surface, which prevents penetration of light.

Silicate of soda (water glass) has found some use in coating a cut surface to obtain a temporary polish. Ordinary varnish has also been tried. These and similar coatings have the disadvantage in that the presence of oil, kerosene or grease will not permit placing an even surface or "gloss" on the specimen. Oil and kerosene are generally used in sawing specimens, and are difficult to completely remove. Therefore an oil soluble has obvious advantages.

DAKE'S VARNISH

A mixture of equal parts of canada balsam and xylol (called *Dake's Varnish*), applied to the surface will give a very satisfactory temporary "polish." Filtered liquid canada balsam is best, but the dry balsam can be used. It is

more slowly soluble in the xylol. The varnish can be applied with a soft camel's hair brush or a soft cotton swab, but best results will be obtained if applied with a spray, in the same manner as quick drying paints are applied. The surface should not be gone over more than once; otherwise streaks will appear. Dipping the specimen in the varnish is also satisfactory. It will require about two hours for the varnish to dry, but if placed in a warm place, like under a strong electric light, setting



Mechanical facet cutting device built by Clinefelter and Larson Company.

time will be lessened. The mixture can be made more concentrated for special purposes, but will require longer to set, unless placed in a warming oven.

One of the outstanding advantages of Dake's Varnish is its relatively high index of refraction, which appears to aid in bringing out a better reflection and "polished" surface. While the varnish can be applied directly on the sawed surface of the specimen, better results will be had if any deep scratches are removed by grinding on the side of the wheel or lapping on the horizontal running lap. What remaining scratches are present will be filled in and become invisible by varnishing. A fairly smooth surface, properly varnished, will defy ordinary observation as being a "doctored" specimen, and is very suitable for its intended purpose.

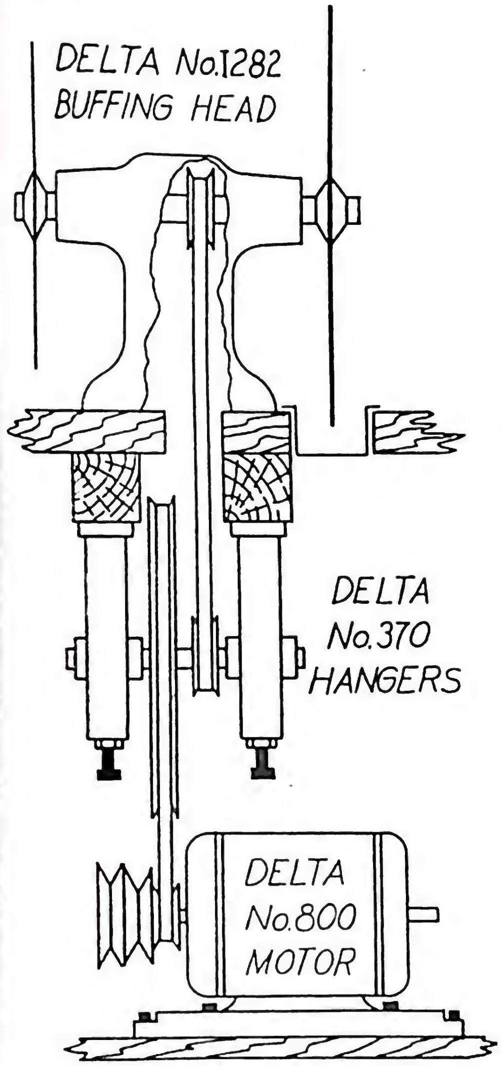
Large thin sections of translucent agate and similar gems are often displayed, mounted in frames, behind glass. It is often difficult and time-taking to attempt to fully polish a large flat surface of this kind. Since the specimens are protected by glass in these illuminated transparency displays, varnishing is fully as satisfactory as a regular polish, especially if the deeper scratches are removed prior to varnishing. Transparencies made of chiastolite and numerous other minerals can be varnished with good effect. Soft minerals are sometimes difficult to finish with a glossy surface, and if they are compact and not too porous, Dake's Varnish will be found effective. Smooth water-worn pebbles can also be treated in this manner.

LAPIDARY NIPPERS

In cutting a cabochon from a sawed slab of agate or similar semi-precious gem material it may be necessary to remove considerable waste material. In order to eliminate considerable grinding or resawing, a special type of "lapidary pliers" can be used to crush or nip off portions of the waste material. This type of pliers is in use in some commercial cutting shops, and the writer wishes to credit the suggestion given here to Oscar Smith of Smith's Agate Shop, Portland, Ore.

The jaws of the lapidary pliers should be well rounded, and the handles about six inches or more in length to give enough leverage. The rounded jaws can be about an inch in length. This type of plier can be obtained in any hardware store at a nominal cost. This tool is widely used for bending wire.

The knack of trimming a slab of agate requires a little practice, as the writer learned. Do not start operating on a valuable specimen. Select a discarded specimen for your first experience. There is, of course, a limit to the thickness of a sawed slab of agate which can be handled in this manner. Sections not over three-sixteenths of an inch can be trimmed readily. In using the tool, select an outermost corner, taking a bite about an eight of an inch deep, and ap-



Details of Delta equipped sawing unit manufactured by Vreeland Company. Speeds can be readily changed to accommodate any type of saw, requiring low or high operation speeds.

ply pressure on the plier handle. This will likely crunch off the irregular corner. When all the projecting corners have been removed by the crushing method, additional and larger fragments can be removed. Hold the agate slab firmly in one hand, apply the jaws of the tool, and with a rolling motion, a fragment about an eighth of an inch deep can be removed.

By following the above outline it will be possible to "nibble" down a fairly large section in a few minutes. After you become adept it will be possible to trim quite close to the finished size, and what is more important, save time on the grinding wheels or the resaw. Do not attempt to clip off large sections. Otherwise you may fracture the section beyond the desired point. The rounded jaws on the tool appear to be more effective in controlling the breaking, compared to ordinary jawed pliers.

RENEWING WORN SANDING CLOTHS

Worn sanding cloths can be "renewed" to be effective for a time by the following technic suggested by John Grieger, Pasadena, Calif. The technic is as follows:

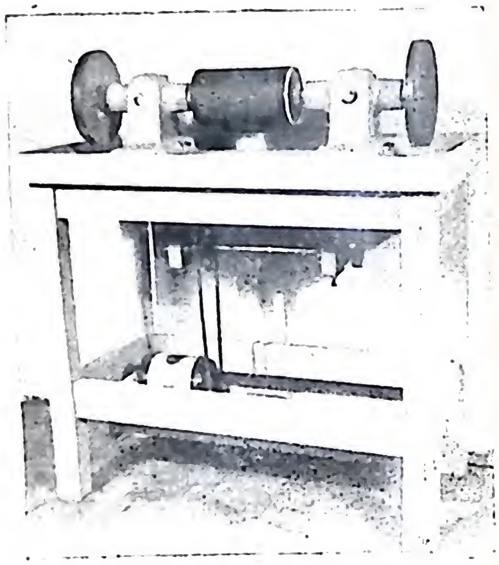
The silicon carbide "sanding" cloths which are used on the vertical type of flat sanding disk, without a projecting nut, can be renewed by simply brushing with a stiff wet brush. The abrasive on the cloth will generally be worn more towards the periphery than at the center; hence in using the wet brush work the abrasive from the center with a circular motion. This can be done in a few moments and experience will indicate the amount of water to use on the brush. Allow the cloth to dry for a few hours, when it will be ready for use. The increased efficiency of this otherwise worn-out cloth will prove surprising.

Naturally there will be less abrasive present than on a new cloth, but the above methods will enable you to obtain several times longer use from standard sanding cloths. The brushing can be repeated a number of times with good effect. The above method applies only to sanding cloths which are factory coated. Cloths which have been recharged by the use of silicate of soda or some similar substance cannot be "renewed" in the above manner.

COATING SANDING CLOTHS

Some lapidarists prefer to recoat their silicon carbide sanding cloths when these become worn. Recoated cloths appear to give good service provided the operation is done properly. The method given below has proven satisfactory.

The worn cloth (free of breaks) is not removed from the vertical sanding disk, but the wheel should be removed from the arbor so it may rest flat. The surface of the cloth is then painted with ordinary silicate of soda (water glass—at the drug store). The freshly painted surface is then immediately dusted heavily with the proper grit silicon carbide, *Norbide*, or whatever abrasive is desired. The disk is then inverted and the excess grit shaken off. Only a certain amount of abrasive grit will adhere and if the coating of silicate of soda is not too heavy or too thin, the surface will function properly. After a few hours of drying the disk will be ready to use. Cloths can be charged in this manner a number of times.



Combination Disk and Drum Type of Sanders, manufactured by the Vreeland Company. Two ten inch vertical disks at ends. Drum stander in middle. A lightweight, self-contained, and portable unit.

If an excess of silicate of soda is applied the charging will be uneven and not give satisfactory service. The consistency of the liquid as it is sold in the sealed container is about right. The can should be kept tightly closed, for exposure will thicken the mixture. The disk should be left resting flat until the soda sets, otherwise the liquid may run and make an uneven surface. Leather sanders can also be charged in this manner.

THE VALUE OF GEM STONES

The factors affecting the value of a gem stone are numerous. To become an expert in appraising the value of a precious stone is a matter which requires years of experience, plus the handling of a great many stones. The purpose here is merely to give the reader some slight knowledge of the manner in which both precious and semi-precious stones are graded as to quality and value.

In general, the principal factors to be considered are as follows: (1) Beauty, (2) Durability (hardness), (3) Color, (4) Rarity, (5) Supply and Demand, (6) Cost of Cutting, and (7) Size.

Opal, for instance, may be, carat for carat, much more valuable than a diamond, yet it is a much softer gem. In this case the opal must be of outstanding beauty to offset its lack of durability. So far as durability is concerned a diamond can be worn for an indefinite period of time and yet show no scratches. On the other hand, an opal, if worn constantly, will, usually after a few years' wear, require repolishing.

Emerald, free of objectionable flaws, of good color and proper size, is the most valuable of all cut gem stones. Although not as hard as diamond, the emerald is quite durable, of considerable beauty and rare in sizes of best commercial demand. Thus several desirable features are incorporated in this gem. Some emeralds may be valued as high as $5,000 per carat, while inferior quality stones may bring only a fraction of this value.

The optical properties of a gem stone also enter into the beauty of a gem. Diamond of commerce is practically colorless, yet its very high index of refraction gives the stone brilliance and "life" and accounts for the flashing play of colors, especially when the stone is seen in artificial light. Colorless zircon shows practically as much brilliance, but, being of inferior hardness, and much more plentiful, its value is less than five per cent that of the diamond. The manner in which a gem stone is viewed has a great deal to do with its appearance. A diamond viewed in the light of a campfire or a dark room with only a single candle, brings forth its best brilliance. An opal is at a distinct disadvantage in artificial light and shows best when worn on a bright sunshiny day. Colored stones like ruby, amethyst and emerald also show well in sunlight. Gem stones of commerce, however, are not graded in this manner. Good daylight is best to note carbon and other flaws. Any gem material having a good index of refraction, even the colorless glass ("paste") imitations, will sparkle with brilliance when placed in an advantageous artificial illumination. A diamond or other stone purchased under the glare of artificial lights will look quite different when viewed outdoors on a drab, cloudy day. Since the optical properties of colorless gems are an important factor in yielding "life," it is obvious gems like colorless quartz and topaz are limited in their brilliance, no matter how they may be cut.

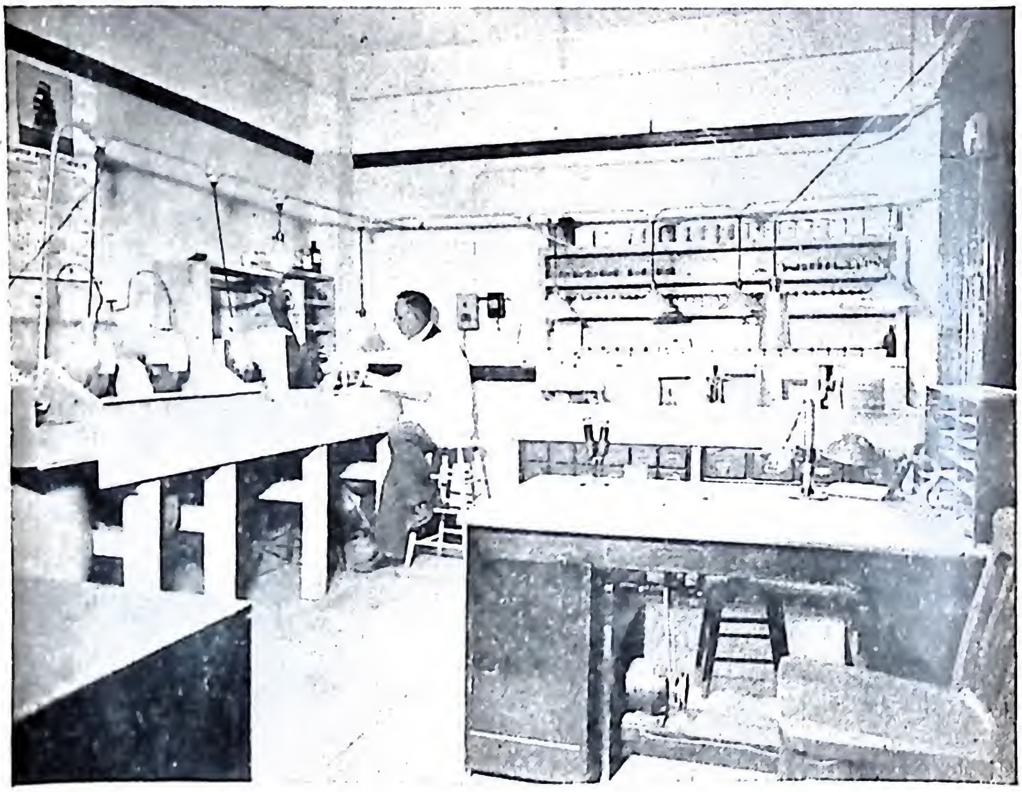
Diamonds are not as rare as generally supposed, but their production is under control by large syndicates. Hence it is possible to maintain a stable price over a long period of years. Amethyst at the time of Queen Elizabeth of England was found in good quality in limited amounts in Siberia only, the result being a value almost equal to that of diamond. Later, when the great deposits of South America were discovered, the price of amethyst was reduced and has now declined to a point where this gem of royal purple, formerly reserved solely for the nobility, is now available to everyone. Thus the factor

of rarity of any gem stone can be eliminated by the discovery of new deposits.

Some of the soft minerals like malachite, azurite, fluorite, calcite and sphalerite would be very popular as gem stones were it not for the fact that they are very soft or subject to marked cleavage. Sphalerite has a very high index of refraction and would be well suited for facet cutting were it not lacking in hardness and availability in the gem cutting. Many of the very soft stones are quite desirable for museum or collection display purposes.

The size of a cut gem is also an important factor in its per carat weight cost. Gems like diamond, ruby (sapphire), and emerald increase in values not in direct proportion comparable to a small stone. For instance, a diamond of one carat is not worth merely twice the value of a half-carat, but generally about four times the value. Gems of this kind weighing over one or two carats are much scarcer than the small stones. In the Orient, especially in India, large, choice diamonds, rubies and emeralds are frequently purchased by princes and potentates and rarely find their way back into commercial markets.

The factor of size is also an influence in determining the value of some of the semi-precious gems. Certain size stones which happen to be in "style" and in good demand will naturally command a premium over odd or obsolete sizes. A very small opal weighing only a carat or two would not be in demand as a setting for a ring. Stones of from five to ten carats would be better suited. Hence the small cut stones, no matter how attractive they may be, would certainly not hold a proportional value. Some years ago pyrope garnet jewelry was very popular. Dozens of very small stones would be mounted in a rather large setting. Today these small gems have a reduced value. A very large cut semi-precious gem may actually be too large for a jewelry piece, but hold its value as a museum or collection specimen.



GEM CUTTING LABORATORIES — THE MINERALOGIST

Fashion plays a very important part in determining the value of some gem stones, especially those generally considered in the semi-precious group. Some ten years ago when the heat-treated blue-green zircons were first introduced in the market, they readily brought from $5.00 to $10.00 per carat (wholesale cost in quantity), and were very popular. Since then good quality zircon has fallen considerably in price, although there is still a brisk demand for the gem. Star sapphire and other asterated gems are now enjoying wide popularity, and an effort is being made to bring back the "old-fashioned" garnet jewelry of our grandmother's days. Demand has a considerable effect on the value of gem stones. Some five years ago the calls for Australian opals were greatly reduced and the price of the gem fell accordingly, but has since been increased considerably.

The cost of cutting is not an important factor in fixing the price of emerald, ruby and similar valuable gems, for, after all, there is no more labor connected with cutting a two carat ruby of the best quality, compared to one of similar weight but inferior in quality. Frequently the presence of flaws and other imperfections in the rough mass will mean the loss of considerable weight, in order to obtain a properly finished stone. When facets are cut on the diamond, there is a loss of from 40 to 60 per cent of the original weight of the rough stone. Hard stones like diamond and sapphire require much more labor than do facet cut stones of amethyst and topaz. In any event, the cost of cutting is, of course, included in the value of any gem stone.

Cabochon styles of cut require less time and less lapidary skill. Some semi-precious gem minerals which are available in large quantities at only a nominal cost are not reckoned in the cost of the finished cabochon. For instance, stones cut from a low grade jasper costing only a nominal sum per pound have a value based wholly on the cost of cutting, plus cost of handling and profit, like any other merchandise. Massive, rough semi-precious cutting material is generally sold on a per pound value basis. Inferior jasper may bring only a few cents a pound, while good quality chrysoprase may cost from $25.00 per pound and upwards. Cut stones of agate and jasper are usually not sold by weight, but at so much per stone. Facet cut stones of amethyst and citrine quartz and similar gems are usually sold (wholesale) on a penny-weight (Dwt.) basis. This is a Troy weight equal to 24 grains, and is designated by the abbreviation, Dwt. It is not the weight of our copper coin. Large jobbers of amethyst (and similar stones) will grade the gems according to size and color, place in separate lots, and price from a few cents up to several dollars per Dwt.

The more valuable facet cut stones are sold on a per carat basis. At present the metric carat is in almost universal use. A metric carat is one-fifth of a gram. A gram is equal to 15.43 Troy grains, hence a carat is slightly greater than three grains. The term "point" is used frequently in the diamond trade and is equal to one one-hundreth part of a carat. Thus a five-point diamond would mean one weighing 0.05 carats.

The term carat (or karat) is also used in designating the fineness of gold, 24 carat gold being pure. If alloyed with, say, six parts of some other metal, the fineness would be reduced to 18 carat (18 K.).

Stones of very rare or unusual color may also bring a very high premium. For instance, a distinctly red or green colored diamond of substantial size may be valued at considerably more than a very fine colorless stone. Very pale shades of yellow or brown detract from the value of diamond. Pure colorless topaz is worth much less than the gems which show a distinct blue color. The ruby, to be classed as "pigeon blood," must have a specific shade of red. The pink stone is not nearly so valuable. Gems of unusual color or some other specific similar feature are classed in the trade as "fancy" stones and bring as much as the highest bidder is willing to pay.

TEN-DAY FIELD TRIP

The annual ten-day field trip of the *Mineralogical Society of Southern California*, and the classes in Geology of Pasadena Junior College is planned for April 8 to 17, inclusive. Present plans call for visits to Mesa Verde National Park, Hovenweep and Natural Bridges Monuments, Grand Canyon, Navajo and Hopi Indian Reservations, and numerous mineral localities.

Visitors may join the field party by making advance arrangements with E. V. Van Amringe, Pasadena Junior College. The party will travel by auto, and lectures on points of interest will be given en route.

The regular meeting of the Society will be held on April 18, featured with a program describing the Annual Field Excursion. A new sound film pertinent to geology will be shown through the courtesy of the Union Oil Company.

PORTLAND MEETINGS

At the April 1st meeting of the *Oregon Agate and Mineral Society*, the new Union Oil Company, geology film will be shown. This motion picture illustrates numerous features of dynamic geology.

On April 15th, Guy Bloomquist, well known Portland gem cutter, will speak on "The Lore of Gems." Both programs are open to visitors.

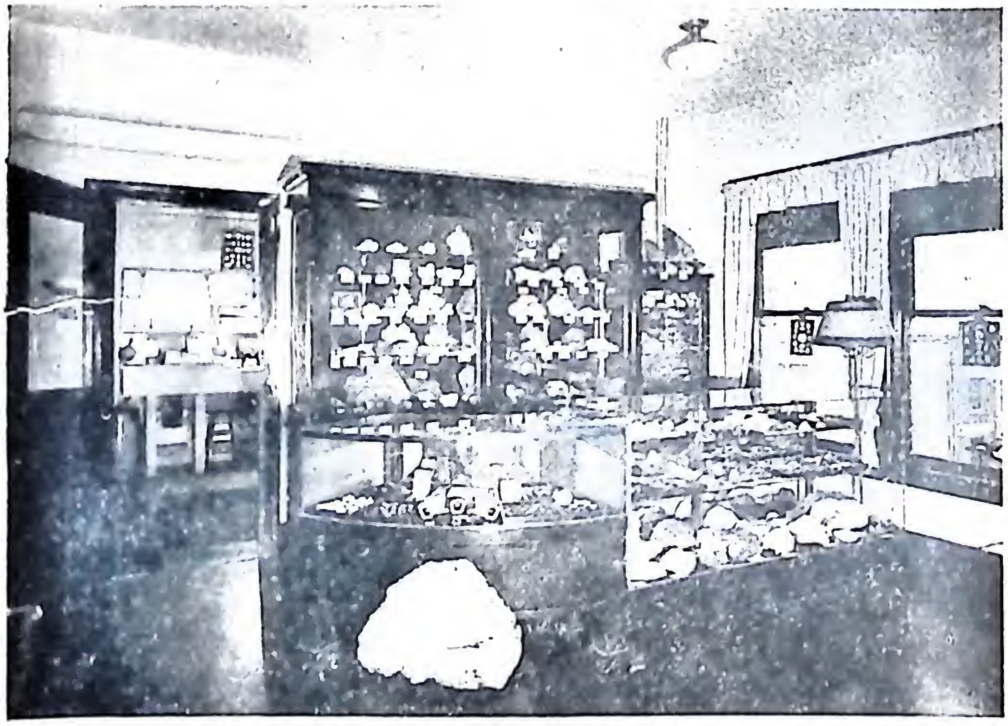
A gem cannot be polished without friction —nor man perfected without trials—Chinese.

USEFUL LAPIDARY NOTES

FOR MUD SAWING—The special "B" grade of *Crystolon* is made purposely for this use. They are special grits which will adhere to the sawing blade better than ordinary silicon carbide.

CABOCHON CUT SAPPHIRE—The removal of deep scratches from cabochons of sapphire can be more readily accomplished with No. 220 grit *Norbide* coated sanding cloth. *Norbide* is at present not available in factory coated cloths. A satisfactory *Norbide* coated cloth can be made in the following manner: A worn silicon carbide cloth is painted with a solution of silicate of soda ("water glass," at the drug store), and immediately dusted heavily with No. 220 grit (or other grit) *Norbide*. The excess is shaken off. Only enough will remain to make an abrasive surface, and in a few hours the cloth is ready for use. The cloth need not be removed from the wooden sanding disk, but should be removed from the arbor. The charging can be repeated on the same cloth for an indefinite number of times. *Norbide* is very much harder than silicon carbide and will attack very hard minerals easily.

GEM SECTION THE MINERALOGIST MUSEUM



North wing of THE MINERALOGIST Magazine Museum, showing gem mineral cases. Museum is open to public without charge. Quartz crystal lined geode in foreground is three feet in diameter and nearly 300 pounds in weight, found July, 1934, at Antelope, Oregon. Entrance to gem cutting laboratories is shown at left. (Photo by Gus Brockmann.)

TESTING AMBER—Among the most common cheap imitations of amber is Bakelite. A simple test will serve to distinguish between them. Amber is very light and will float readily in strong salt water, while Bakelite and similar substitutes will promptly "hit bottom." Hence, if the lady's strand of beads sinks in a solution of salt water, you can confidentially inform her, if you dare, that there is something wrong. The cheaper types of amber—the "pressed" and "moulded" varieties—will of course float, since they are actually the real article.

TURQUOISE—There are numerous substitutes for turquoise and care must be exercised in passing opinion on stones of this kind. The ruby was originally made by fusing together very small fragments of genuine material to obtain a larger and more valuable gem. So are sometimes large masses of turquoise obtained, except that heat is not used, but small fragments are pressed together; and probably some cementing substance is added. Turquoise is rarely found in rough masses large enough to cut a large stone. Hence, the large, inexpensive (or expensive) gems sometimes sold may be a worked-over turquoise or an out and out imitation. Care should be exercised in permitting a fine turquoise to come in contact with oil or

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soapy water. The gem should occasionally be cleaned with dilute ammonia water, which also aids in improving the color.

IMITATIONS—The ingenuity of man has reached a point where a great many gem stones can be manufactured in excellent imitations, which may even pass the casual observation of an expert. A new type of synthetic emerald is on the market or will appear in the near future; this material is said to show strong dichroism, as does the natural stone. Probably as many European manufactured stones are sold in the Oriental gem producing countries as in some other places in the world. The unwary tourist often goes on the assumption that a stone bought in a gem producing center is likely to be the real thing. You are more likely to get fair treatment from your home town jeweler whom you know, than from the hands of the unknown Oriental merchant. The fact that a stone originated in a gem producing center is no criterion of its having been mined. The natives in the gem producing centers have even been clever enough to purchase an uncut boule, shape it like a water-worn pebble and place it in a lot of mined material. The trick has worked. Remember, too, that good, genuine stones are not sold at "bargains" to tourists on the streets in an Oriental gem center; no more than one would expect to buy gold nuggets at reduced rates in a mining camp. Both have a standard value which the producer can readily obtain in the regular markets.

DICHROISM OF RUBY—Due to the peculiar splitting of corundum boules along their optic axes, it is uneconomical to cut them perpendicular to the optic axis, as the natural ruby and sapphire are generally cut. For this reason a synthetic ruby may be dichrotic through the table, while the natural gem is usually isotropic in this direction. Any stone which is claimed to be natural and which shows dichroism through the table should be carefully examined before passing judgment. A few natural rubies and sapphires are cut against the above rule for various reasons, including the presence of spots of color, flaws, and imperfections.

ALUNDUM ABRASIVE—The mineral bauxite, fused in an electric furnace of the arc type, is purified, crystallized, and becomes the familiar abrasive and polishing agent, *Alundum*.

In chemical composition the *Alundum* abrasive resembles sapphire and emery. The main characteristics of the artificial material, *Alundum*, is its toughness, hardness, and highly uniform purity and quality. It is used universally as a polishing powder in the lapidary industry.

POLISHING DATOLITE — The fine, massive, compact, specimens of datolite, showing native copper, which occur in Michigan, often present a problem to polish free of scratches. Seem-

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ingly small fragments of native copper are torn from the specimen and carried across the surface by the felt buff. Generally the copper is found along the edges of the nodular masses of datolite; hence, if the polishing is directed from the center toward the edge much of this scratching will be eliminated.

SANDING—The surface of a large specimen should be sanded in one direction, preferably along the natural pattern of the stone. This practice tends to obscure any scratches that may be left after polishing; in other words, any remaining scratches would blend in with the natural layers or lines of the agate or whatever material was being worked.

ADAPTING SANDING CLOTH—Wrinkles may appear when adapting the sanding cloth over the working face of the vertical running type of sander. In order to get a smooth adaptation of a new sanding cloth, the back (not abrasive side) side should be made slightly moist with water. This will soften the cloth and permit easier adaptation to the face of the wooden disk.

On this type of sander the cloth is generally held firmly in place by the use of a metal hoop, fitted tightly over the slightly tapered periphery of the wheel. Some workers cut a groove on the periphery of the disk, and hold the sanding cloth in position with a heavy rubber band cut from an old inner tube. In both cases the dampened cloth can be more easily adapted.

TOURMALINE CABOCHONS—Gem quality tourmaline, free of all flaws and suitable for facet cutting, is by no means common material, and generally cannot be had at a low price. Tourmaline often occurs in good quality so far as color is concerned, but all too often the crystal is found flawed, rendering it unsuitable for facet cutting. Excellent cabochons can often be worked from these crystals; small bi-colored crystals where the colors meet in such a fashion as to permit finishing a stone showing equal portions of color are especially attractive. Some types of green tourmaline exhibit a fibrous effect, and this material even when flawed will frequently yield choice cabochons which present a "cat's eye" effect. The

Thomas Warner collections of tourmaline contains a great many cabochon cut stones, which offer ample proof of the possibilities of the cabochon style cut.

NORBIDE SPEEDS SAW—One of the chief objections to the "mud" saw is the slowness of the operation. The mud saw can be speeded up by adding a small amount of *Norbide* to the silicon carbide mixture. *Norbide,* a recently developed product of the electric furnace, is, the hardest substance yet made by man on a commercial scale. It is considerably harder than silicon carbide or sapphire. This new abrasive is available in numerous standard size grits.

No specific amount of *Norbide* is advised, but the more added to the silicon carbide mix the greater will be the efficiency of the mud saw. *Norbide* has a low specific gravity, about half that of silicon carbide. Hence this newly developed abrasive will not tend to settle in the "mud" mixture. Further, a pound weight is about twice the bulk of a pound of silicon carbide. No. 120 is the usual size grit used in the mud saw.

CARE OF MUD SAW—The periphery of the mud saw tends to become tapered after considerable use. Hence it is advisable to trim off an eighth or a quarter of an inch from time to time. This will also true the edge as well as remove most of the tapered portion. The trimming can be done with a sharp fractured piece of agate, holding the cutting tool on a firm steady rest against the saw edge while in motion. A sharp steel tool can also be used for the trimming. Speeds over about 300 R.P.M. (other size disks in proportion) for a twelve-inch disk will produce "flats" more rapidly.

CABOCHON BEZEL ANGLES—The beginner in cabochon cutting is often at a loss to know what angles should be made on the edge or girdle of a cabochon cut stone. This will be dependent on what purpose the stone is for. If it is merely a gem that is for display purposes only and not to be mounted, it matters little what angle is left at the "bezel" portion.

If the stone is to be mounted consideration must be given to the type of mounting to be used; otherwise the manufacturing jeweler may have difficulty in properly mounting the gem. If the stone is to be mounted in a heavy cast sterling silver mounting, then only a slight angle need be given the bezel portion. Measuring the slope from the flat base, the angle should be approximately 10 degrees. The reason only a slight angle is given for this type of mounting is the difficulty of pressing or bending a heavy mass of silver. On the other hand, if the gem is to be mounted in a gold mounting where thin strips of gold are bent by hand to form the bezel, then from 20 to 30 degrees slope should be given to the side of the stone. Similar silver mounts can be given a slightly less angle.

A cabochon cut stone lacking the

proper angle for the given type of mounting will tend to loosen in the setting. Generally a cabochon gem that becomes loose in the mounting can be charged to incorrect cutting or careless work in mounting, or, of course, rough use of the ring may loosen any stone in its mounting.

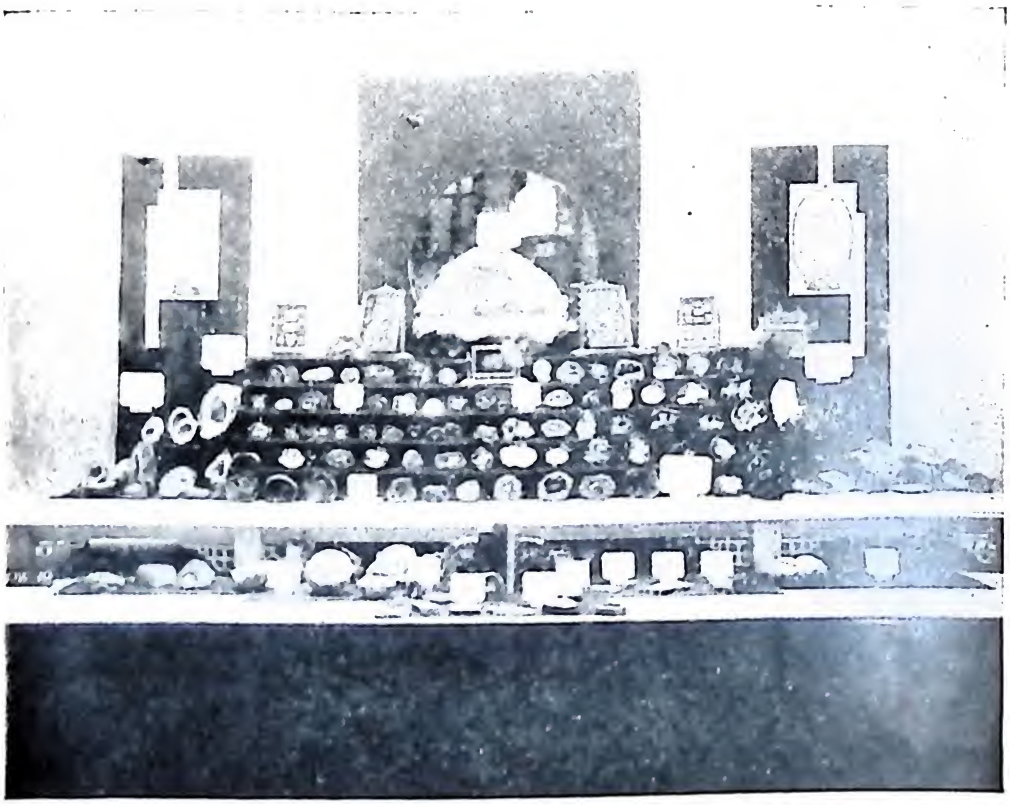
LAPIDARY PENCIL

A piece of ordinary aluminum wire about three inches long and ground to a long point at one end, is very useful to the lapidarist. The pointed end is used to outline the desired final shape of the cabochon set to be cut, using it like a pencil on the flat sawed surface of the gem material. The advantage of the aluminum pencil or wire over an ordinary pencil is that it will not rub or wash off during the grinding process, and the mark can be seen when the rough gem is either wet or dry. As a matter of fact about the only way to remove the aluminum markings is to erase them, with a bit of old abrasive cloth.

Another use the writer suggests for the aluminum pencil is aiding in cutting a uniform height of bezel on a cabochon cut set. While shaping out the blank to the desired size and shape for the cabochon in question, work with the back of the cabochon up and slope the cut about thirty degrees from the perpendicular. (Note: For cast mountings such as heavy sterling silver rings, it is advisable to give about fifteen degrees slope to the bezel.) We now have a blank oval, round or square, about an eighth of an inch thick and correct slope inwards around the edge. With blunt end or side of the aluminum pencil, shade the entire one-eighth inch sloping edge (more or less) of the blank with the aluminum pencil. Let us assume you wish to have a finished stone with a bezel one-sixteenth of an inch high. As you round off the top of the stone it is quite easy to see exactly how uniform you are cutting the bezel, or to put it another way, just where you have to remove material to obtain a bezel of uniform height all the way round.

OPAL TREATMENT

A number of methods have been suggested for the treatment of opal to prevent cracking or "checking" after being cut. Some of the fine grade Nevada opal is unfortunately subject to the development of small irregular cracks, which may appear some months or even years after the gem is cut.



Public exhibit of cut and polished specimens of semi-precious gem minerals, the work of members of the Oregon Agate and Mineral Society. (Photo by Gus Brockmann.)

Since opal is a hydrated silica, it was thought that some substance like silicate of soda (water glass) might act as filler for the minute fractures, and thus prevent further cracking. The object being to soak the gem in the solution and then by drying at ordinary room temperatures the water glass might act as a cementing agent or a "filler".

J. Lewis Renton, of Portland, Oregon, observed a fine twenty-carat Nevada opal in his collection which was developing minute fractures over the outer surface. Presumably this "checking" was the result of a slight dehydration. The stone was placed in a silicate of soda solution, for a number of weeks, then removed and allowed to dry for a few weeks. This treatment was repeated in a systematic manner over a six-months period, and the stone closely observed from time to time. The treatment in no way appeared to improve the opal, as a matter of fact the continued soaking only made the gem appear worse. After treatment ceased the checking did not appear to continue as rapidly. In short, the experimenter could not recommend the treatment.

Possibly other stones might be improved by the silicate solution or some similar treatment, as opals are obviously variable in water content. So far as is known no satisfactory treatment has been developed for the prevention of fracturing in opal. Occasional soaking of the gem in paraffin oil or glycerine seems to help some gems, but this again is open to debate. The manner in which Nevada opal has been handled in cutting seems to have some effect upon their stability. Expert opal cutters have made the observation that Nevada opal which has been carefuly cut on the grinding wheels, using a fine grit wheel (No. 220), and avoiding undue heating of the gem, will tend to check less than stones cut carelessly. Moreover, while the gem is being ground hot water should be sprayed on the wheel, rather than cold. Friction will create a certain amount of heat at the point of cutting, hence with hot water the sudden chilling is lessened. Some commercial lapidary shops have a hot water connection to the grinding wheel especially for opal cutting.

RICH GOLD MINE

One of the best instances known of a gold mine in steady production over a long period of years is that of the famous Homestake Mine in South Dakota. Since its discovery in 1876 this mine has had not only a steady production, but has produced nearly $300,000,000 in gold.

The Homestake Mine does not depend upon rich ore but upon its very large and persistent bodies of quite low grade ore. Thousands of tons of low grade ore are removed daily and sent through the modern mills for treatment and much of it is worth only a few dollars or less to the ton. The history of this remarkable mine is also the history of the advances made in metallurgical work, for on numerous occasions in the past it appeared that operation would become unprofitable, without economies being instituted in the ore milling. However, the many problems encountered have been dealt with successfully, often at considerable expenditures, but profitable operation was maintained throughout the years.

LEATHER SANDERS

The actual polishing of a cabochon style cut gem or specimen, is a matter of ease and simplicity, once the stone is free of deep scratches and ready for the felt buff wheel. It is getting the stone or specimen ready for polishing, smooth and free of all scratches, that presents the hardest problem for the gem cutter. This is generally done on a wheel termed a "sander."

The methods in use for sanding are varied and numerous, but in principle all are similar. Special cloth, coated with Crystolon (silicon carbide), Alundum, Norbide, or Carborundum, and stretched tightly over a wooden wheel, is an effective method in common use. In certain types of work or by careless handling, the cloth may tear, and as an alternative for cloth under these conditions a piece of soft and pliable leather may be coated with the proper grit abrasive powder and used in place of the cloth. Leather can be used in either of the two types of sanders; the vertical running type, where the work is done on the side of the wheel, or the "drum" type of sander. The operation of the "drum" type of sander has been described in detail by J. Lewis Renton in an article appearing in the June 1937 issue of this publication.

The circular piece of leather is stretched over the side of the wooden wheel, which is usually about ten inches in diameter, and held in position by an iron hoop. The wooden disk should be about two inches thick and a slighty tapered periphery will aid in securing the hoop. Over the surface of the leather (pelt side out), paint a coating of silicate of soda ("water glass" purchased in drug store) and dust on thickly the abrasive powder and immediately shake off the excess. Enough of the abrasive grit will adhere, and the application of the silicate of soda should not be too thick; a little experience will indicate the proper consistency. After setting for a few hours the sander is ready for use. Subsequent charges of abrasive can be readily added as it is worn away, without removing the leather from the wooden disk (but remove wheel from shaft), in fact the sander will work much better after it has seen some service.

A fine grit silicon carbide, either 220 or finer, is generally used on sanders, and they are operated at nearly the same speed as the grinding wheels, 1200 to 1400 R.P.M. being suitable for a ten-inch sanding wheel.

If the side of the wooden disk is made slightly *concave*, this will tend to hold the leather in suspension and will act as a cushion and facilitate sanding of cabochon (rounded) stones. However, if large flat surfaces are to be polished, the side of the wooden disk should be *convex*, with about a ¼-inch raise at the center of the working surface. The convex surface is usually padded with about a ¼-inch thick layer of felt to act as a pad for the leather or cloth coated with abrasive. Do not attempt to polish a specimen until all deep scratches have been removed by the sanding operation. A few minutes longer spent at the sander will save considerable time at the polishing buffs. Sanders are usually run dry.

The best type of vertical running sanding wheel is where the shaft is threaded and sunk into the body of the wooden disk, thus leaving the entire working surface of the disk free of any projections. This will enable the operator to sand large flat or rounded surfaces by passing back and forth across the unobstructed sander surface.

CRAWFORD SAWS

The F. H. Crawford Company lapidary sawing unit (illustrated in advertisement), can be used with either a diamond or "mud" saw. The unit is sturdily built for heavy service, ball bearings are used with cast iron casting. Very thin or thick sections can be cut at the selection of the operator. The unit is ready for use and will operate satisfactorily with a ¼ horsepower motor. A twelve-inch saw blade can be used.

The Crawford Company also manufactures a 24-inch automatic lap wheel, mounted on a metal stand, complete, and ready for use.

QUARTZ - AGATE BOOK SOON READY

The new book QUARTZ FAMILY MINERALS, "A Handbook for the Mineral Collector," will soon be ready for distribution, reports McGraw Hill Company, New York City book publishers. The price will be $2.50.

The book will appear mainly in semi-technical language, especially written for the lapidarist, layman, mineral collector, and retail jeweler. It will be the only complete work of its kind in the English language, and will fully describe the many varieties of the silica minerals including agate, quartz, jasper, chalcedony, opal, petrified woods, and some 200 varieties and sub-varieties. Localities will also appear to better enable the collector to use the work as a field guide. Dozens of new localities not previously described will be included. Numerous new illustrations will appear.

QUARTZ FAMILY MINERALS is the work of "The Three Agateers," Ben Hur Wilson, Frank L. Fleener and Dr. H. C. Dake, and represents the accumulated effort of years of study and observations. A great many of the localities and areas where quartz gems are found, were visited personally by one or more of the authors, hence a great deal of the data presented is from first hand observations. Little space is devoted to foreign localities, for after all it was felt few readers of the book would be enabled to visit these localities, and space devoted to American localities would prove of greater value.

Advance orders are being received by all mineral distributors and book dealers. *Send in your advance order now* and be assured of receiving one of the first copies off the McGraw Hill Company presses.

TO THE OPAL COUNTRY

(Book Review)

OPAL, *The Gem of the Never Never,* published by Thomas Murby Co. of London, in 1924, has been only slightly read in America, due perhaps to lack of publicity given this work.

T. C. Wollaston, the author and a pioneer Australian opal buyer, tells of his experiences in the opal fields in an easy reading style. In the preface he apologizes for his "unorthodox" style of writing, but American readers are sure to find this work of intense and fascinating interest. The journeys of Wollaston are set down in some detail, and includes interviews with various characters met within the opal fields.

At the time the author first visited the interior Australian opal fields, travel was much more primitive than at present, and his many anecdotes will bring smiles to the reader. Wollaston has his own opinions as to the mode of the deposition of opal, and described in his free and easy style. Included in the work are three excellent full page color plates and eleven full page photographs of opal localities. In Part III, "Sketches of Opal Field Characters," will give the reader an insight on the mining of opal. *Paul's Patch* or *The Woman in the Case,* being one of the best.

OPAL, *The Gem of the Never Never,* price $3.00, has been placed in the stocks of some American dealers whose advertisements appear in these pages. This will enable the reader to obtain the book without delay and the necessity of sending foreign money order.

VISITS HORSE HEAVEN

While on a 5,000 mile tour of the western states S. G. Coultis of Calgary, Canada, visited the Horse Heaven Hills of Washington locality, described in the May 1937 issue of THE MINERALOGIST Magazine. We quote in part from a letter received from Mr. Coultis, who is field geologist for the Imperial Oil Company of Calgary, (Alberta) Canada.

"Now referring to the Horse Heaven Hills visit, we arrived there and found the canyon without difficulty * * * obtaining all the fine colorful specimens the wife and I could carry to the car. About a mile up the road from Roosevelt, where the main road makes a sharp bend they have recently cut through some real stuff. Within a layer of white volcanic ash we found opalized wood of a beautiful green color. About three feet below the original ground surface someone had been digging for specimens so I started to dig and removed a section of opalized wood about eight inches in diameter and by further digging I managed to obtain an additional colorful specimen measuring 8x18 inches, a complete log section. Opalized wood and seams of opal and chalcedony appeared to be exposed at numerous places along the highway, but unfortunately time did not permit investigation.

"Then some 20 miles further on when we started to descend into a valley, leaving the Horse Heaven Hills, on the right side of the road in a deep cut I noted a peculiar exposure. Investigation show a silicified vein some 10 inches in diameter, amorphous material and mainly common opal, but very colorful in its many shades, all in the same vein. Well the car was about bogged down so very little additional material was added to the groaning springs * * * the writer wishes to extend thanks to THE MINERALOGIST Magazine in publishing the article which led us to the localities where so splendid material was readily available."

VERNONIA LOCALITY

Tom McAllister, one of the many active members of the *Journal Junior Mineral Club,* Portland, Oregon, made a week end visit to a locality on the Nehalem river, near Vernonia, Oregon and found some choice specimens.

To reach the locality take road leading

west from main highway a few miles south of Vernonia. Follow the side road about a mile and make a local inquiry at farmhouse. The turnoff place is near the camping park on highway.

Accompanied by his father, Dr. T. H. McAllister, prominent Portland dentist, Tom junior was enabled to add some excellent specimens to his collection. Included in the find was a superb example of very deeply colored carnelian agate, a specimen of 5x5 inches, and one of the finest gem pieces ever found in the Pacific Northwest. A good supply of the remarkable fossil "crabs" was also obtained.

So far as can be learned fossil teredo wood has not previously been reported from this locality, but Tom found one water worn specimen in the gravels of the Nehalem river. The specimen measuring 3x3x8 inches, is almost identical in appearance to the Teredo wood found near Roseburg and recently described by Jack Wharton (April 1937). The wood species in which the fossil teredos occur has not yet been determined but in all probability the Vernonia material is contemporaneous to that of Roseburg.

Very little collecting has been done at the Vernonia locality, hence the area offers a good field for study. Various fossil shells are abundant, the zeolites occurring in the lavas are of good quality, while the gravels of the river yield an occasional high grade gem carnelian and jasper.

OUTCASTS OF THE UNIVERSE

GLADYS C. RANDOLPH
Berkeley, California

A great fiery ball streaked across the calm starlit sky, a glaring trail of light and sparks marking the bright arc of its downward flight. With a deafening roar and crack, the dazzling mass extinguished itself in the blaze of its own brilliance. The amazing spectacle and thunderous salute announced the coming of a visitor from space — one of the most sensational and romantic events in the light of science — the fall of a meteorite.

Not all meteorites — the meteors which have fallen upon our planet — arrive with pomp and show. Some slip down without any special phenomena of light and with scarcely perceptible sound, while the passage of others through space and their arrival upon earth is marked by the most magnificent drama of the heavens — an awe-inspiring show, sometimes both startling and violent. The vast majority of meteors, "shooting stars" and "fireballs" never become meteorites, as fortunately the earth is guarded with a protective layer of atmosphere more than 200 miles deep; otherwise, we would be subjected to a terrific bombardment, which would make life extremely hazardous or entirely impossible. Since it is estimated that the meteor's speed through space is about 40 miles per second (while those very few actually reaching the earth are slowed up to approximately 13 miles per second), appalling destruction would certainly follow in the wake of an unimpeded fusillade.

While the arrival of a meteorite may sometimes be one of spectacular incidents of Nature, there are few objects of less aesthetic appeal; and yet the ugly blackened mass furnishes the only tangible evidence of the nature of materials existing in our own or other solar systems. Although all elements found in meteorites occur in terrestrial rocks and minerals, the differences are mainly in percentages and degree of oxidation, and moisture. It would appear that perhaps meteorites occurred where oxygen and moisture are lacking or only present in small amounts.

However, although meteorites are the only concrete means we have of gaining something definite as to the composition of the Universe, their preservation for scientific purposes was not undertaken to any extent until about the beginning of the 19th century. The first collections were formed in the museums of the capitals of Europe and most of these have been admirably maintained. No science is more dependent upon the help of the layman than the study of meteorites. Nobody knows where the next specimen will fall or be found and our whole knowledge of the phenomenon must come from the lucky observer who just happens to be on the spot, or the chance finder — the prospector, the mineral collector, the hunter or the hiker, perhaps. It is important that we be on the lookout for one of these "wanderers" of space, for it may be the bearer of a real "news scoop" from the skies.

There are three principal types of meteorites, classified according to composition, as *siderites*, these consisting almost wholly of iron; *siderolites*, having a cellular matrix of iron in which stony matter is embedded, and *aerolites*, composed almost entirely or wholly of stony matter.

An iron meteorite is very easy to recognize, as it will always be very heavy and attracted by a magnet. If newly fallen, it will present a blackened exterior and if an old fall will probably be reddish-brown with rust, and the surface will often be pitted with thumb-like impressions. The metallic meteorites are by far the most interesting and puzzling of all. Meteoric iron is massive, but its crystalline structure can be discerned when its face is polished and etched lightly with dilute nitric acid, when figures or marks, formed of parallel bands intersecting in two or more directions, usually appear. The markings are called Widmanstatten figures. How meteorites happen to have these figures is not clearly understood, although it has been shown that when heated to a low red heat, they are lost. This would indicate that the meteorite, in passing through space, had not been heated to even redness, the outer incandescences being only superficial from friction, while the main bulk remained cold. Any piece of iron not readily accounted for in some other way is a good meteorite "suspect" and should be subjected to expert examination.

A stony meteorite is harder to identify than an iron, but it too will be heavier than the average earth-stone and may also have a similar external appearance as the irons. If ground on a grinding wheel, the exposed surface will reveal tiny grains of metal visible to the naked eye or under a microscope. But questionable material should be referred to an expert.

Meteorites seen to fall are termed "falls," while those determined from internal characteristics are called "finds." A far larger number of stone than iron meteorites have been observed to fall, but among the "finds," the irons predominate. It has been estimated that there is probably not an area five miles square anywhere in the United States where at least one meteorite is not fallen and since crumbled to dust. Broadly speaking, there appears to be no fundamental reason why meteorites should be any more numerous upon one part of the earth's surface than another.

During flight, the heat generated by friction with the atmosphere fuses a thin outer surface of the meteorite, especially on the foremost part of the body, and causes the melted material to flow back in waves, making a kind of "varnish." The common belief that meteorites are intensely hot throughout is erroneously based on the brilliant light emitted, while passing through the atmosphere. The thin film on the surface, which may become fused, is immediately swept away by the pressure of the surrounding air, hence they slough away rapidly.

The forms of meteorites seem to depend chiefly upon the amount of shaping which they undergo in their flight through the atmosphere. This may in turn depend partly on the speed, a lowered velocity giving more time for shaping. Meteorites which break up shortly before reaching the earth present irregular forms, such as a rock broken by a hammer might show. Apparently there is no limit to the size of meteorites, the largest known weighing many tons, and the smallest but a few grams. It is now generally conceded that meteorites, of whatever size or type, are fragments at the time they enter our atmosphere, and that further fragmentation in size takes place through surface sloughing or breakage. Iron being tougher and more resistant than stone, it would naturally follow that among the metallic forms, the larger specimens would prevail. This idea is further borne out in the fact of the frequent occurrence of showers of stony meteorites, rare among the "irons."

One of the theories to account for the shattering so common to meteorites (stony principally) when they enter the atmosphere of the earth is the fact that the thin outer layer may be incandescent, while the bulk of the material may be very cold. This great inequality in external and internal temperatures, plus the heavy pressure of friction, could account for the frequency of shattering "explosions." All known meteorites are composed of volcanic materials and none of them are believed to show within them traces of animal or vegetable life, unless the carbonaceous matter is to be so considered. Being igneous material in origin, meteorites can be looked upon as an unfavorable medium for the preservation of any life, even if same was present at their place of origin.

It seems strange, when the theories of the earth's history are considered, that nothing which can with certainty be ascribed to meteoric origin has been found in terrestrial beds of any geological formation except the most recent. If meteorites have fallen during very early periods, they may have been of a different type, or what is more probable, they have become thoroughly decomposed or otherwise altered, so as to be unrecognizable.

Myriads of meteors continually enter the earth's atmosphere and at night many of them are seen to pencil the skies with streaks of light, but their usual fate is to be consumed in their own blaze. Many enter the atmosphere at such an angle that they leave it without coming close to the earth, while others reach the earth as cosmic dust, in grains, or even masses many tons in weight.

The largest meteorite in "captivity" is the Ahnighito from Cape York, Greenland. This "iron" of 36½ tons is in the American Museum of Natural History collections. The "Hoba West," a more recent find, estimated to weigh about 60 metric tons, is still lying where it fell near Grootfontein, South West Africa. The largest meteorite ever found in the United States is the Willamette "iron," found near Portland, Oregon, and weighing, when found some 15 tons. A smaller casual visitor, weighing 820 pounds — the largest "stone" on record—dropped in on Kansas in 1930. In Arizona exists the largest known "tomb" of a meteorite—Meteor Crater—a gigantic pit nearly 600 feet deep, with a three-mile trail around its rim. And with the giant "envoy" from the skies came a royal gift. Enclosed within some of the meteorite fragments found in the vicinity were minute diamonds.

As meteorites have been considered rare and inexplicable since early times, it is not surprising that they have in many instances been endowed with both superstitious and religious significance. An iron which probably fell about 1400 A. D. has been preserved in Bohemia where the mass is known as the "Bewitched Burggrave," as according to tradition it represents a tyrannical court official whose body was converted to iron as punishment for his many cruelties. Several stony objects kept in the temples of the Greeks and Romans are supposed to have been mete-

(Continued on Page 105)

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orites and the sacred black rock in the Kaaba at Mecca, with its once rough exterior now worn smooth by the kisses of adoring millions, is also believed to have come down from space. A "message" from the sky was found in a temple of the Aztecs, another in a cliff dwelling in Colorado, while several are said to have revered places in Japanese houses of worship. Apparently, the blackened stones from the heavens had a universal appeal since the earliest times.

Today, the scientist looks upon a fragment of a meteorite as a most vital clue to the composition of the Universe, and although his telescope reports that our sphere moves in tune with stars, suns and planets, his "outcast from the sky" does more. It is something tangible to examine, analyze and compare with the minerals of the earth; and it tells him that the far-off shining stars are, after all, but the substance of the earth, and the substantial earth upon which we walk is really "star dust."

EXPERIENCES OF A MINERAL COLLECTOR

DR. H. C. DAKE

Field trips and vacation tours do not always yield the mineral collector a large number of choice specimens, but in the experience of every collector, a real "find" will be made at some time or other. Perhaps it may be of interest to briefly detail an account of the "red-letter" day experienced by the writer some years past, while on a collecting tour of the Pacific Northwest.

Mineral collecting in the western states is usually not carried on at rock quarries, so often lucrative localities in the far eastern states. The mining districts in the western states present by far the most likely localities where good mineral specimens are available. In some districts where extensive work has been done, the enormous dumps of waste gangue minerals comprise good fields for search, the material is loose and at least a superficial search can be made without the use of tools. Sometimes even the small amount of material removed from a prospect hole will yield good specimens. But to get back to the "red-letter"day.

Arriving in August, 1929, at Spokane, Washington, the writer called upon genial Charles Fernquist, curator of minerals at Spokane Public Museum, who was to accompany him to some of the many localities in the vicinity of Spokane. We decided to first visit the old abandoned Cleveland Mine near Hunter in Stevens County, some 100 miles from Spokane. Stopping at a small town on the main highway, to make inquiry concerning the condition of the side-road to the mine, we met one of the owners of the Cleveland Mine. This gentleman kindly gave us detailed directions to the mine and assured us there was nothing of interest there, it was full of water, the buildings in ruins and practically all that remained was the huge dumps of waste material. This, however, did not appear discouraging, for it was the dumps that held our interest, and the mine official generously gave us hearty consent to "help ourselves to anything in sight."

Arriving at the abandoned mine late in the evening we made no effort to search the dumps, but spread out blankets for a night under the canopy of stars rapidly gathering overhead. With the rising sun warming the chill mountain air, we "rolled out" and started our search of the old dumps. After some hours of search we had obtained a number of small but choice specimens of boulangerite, bindheimite, mimetite, arsenopyrite, octahedral calcite crystals, epiboulangerite (?), and a number of others for which this locality is noted. The boulangerite was the chief object of our visit. Specimens can yet be found on the old dumps, but generally only sparingly, unless the collector is lucky. The pure masses of long fibrous boulangerite encountered in the workings are probably equal to or better than that of any other locality in the world.

About noon we decided to look under the flooring of a broken-down ore bunker, for good specimens can sometimes be found in unexpected places. The space under the ore bunker proved

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PICK AND HAMMER CLUB — P. O. Box 2297, San Francisco, Calif.

GEOLOGICAL SOCIETY COEUR D' ALENES — Arthur E. Cooper, Kellogg, Idaho.

SEQUOIA MINERAL SOCIETY — Sect. Dora Andersen, Rt. 1, Box 258, Parlier, Calif.

WASHINGTON AGATE-MINERAL SOCIETY — Ray C. Gruhlke, 207 Capitol Theatre Bldg., Olympia. Meetings first and third Saturdays.

DESCHUTES GEOLOGY CLUB — Sect. Thelma E. Perry, Box 5, Bend, Oregon.

SAN JOSE MINERAL SOCIETY — Sect. Alfred J. Case, 720 South Third St., San Jose, Calif. Regular meetings.

SACRAMENTO MINERAL SOCIETY — Sect. Fern Bradford, 2505 27th Street, Sacramento, Calif. Regular Meetings.

STOCKTON GEM AND MINERAL CLUB — Sect. Mrs. Luella Brittsan, 1320 Buena Vista Ave., Stockton, Calif.

a bonanza. It appears, at the time the mine was in operation (base metal mine), the smelter would penalize ore with antimony content, hence when fine large masses of boulangerite were encountered in the workings, this material was sorted out before the ore was crushed. Evidently in order to keep the huge masses of antimony-bearing boulangerite from finding their way into the milling ore, the workman at the sorting table cast these choice specimens under the floor, where they remained for years, overlooked by others who had visited the locality some years previously. Needless to say when we had recovered hundreds of pounds of fine masses of boulangerite, in a few minutes by merely lifting same from below the floor, we felt we had a most successful day and promptly lost interest in the dumps. Of the many thousands of temporarily or permanently abandoned mine workings in the west there are undoubtedly some which would prove a similar bonanza for the collector.

In a recent issue of THE MINERALOGIST, C. D. Woodhouse, in an article, "Mines Can Profit by Specimen Sales," called attention to the fact that mine operators frequently cast on the dumps material having good specimen value. This was certainly true at the Cleveland Mine, for undoubtedly thousands of dollars' worth of superb boulangerite and other minerals are covered in the huge dumps.

OREGON GEM CLUB

The *Southwestern Oregon Gem Club*, recently celebrated its First Anniversary, with a banquet meeting and a colorful display of specimens. New members are coming into the Club at a steady rate. The Club will likely affiliate with the Northwest Federation.

Officers elected for the year include: President, J. R. Elder; Vice-President, A. Donley Barnes; Secretary, E. A. Starkweather, and Treasurer, Pearl Forrest. Meetings of the Club are held the First Tuesday, Grants Pass Library, and the public may attend.

It is more blessed to give than to lend — and costs about the same.

AMBITIOUS INDEED

In response to the article, "Ambitious Collector," appearing on page 12, September 1936 issue of THE MINERALOGIST, Louis Cassinat of Rawlins, Wyoming, sends us a rare photograph and description.

The article referred to above calls attention to the collecting propensities of the western "pack rat." This unique mammal includes among other things in its museums, colorful fragments of various minerals and rocks.

In searching for fossil wood, agate, jasper and other materials on the Red Desert, twelve miles west of Rawlins, Wyoming, Mr. Cassinat discovered the huge pack rat nest shown in the accompanying illustration. The nest or "museum," as it may be termed, contained every imaginable object that could possibly be found on the desert, including many bright colored pebbles, agates, petrified wood and a human skull and some bones.

The human skull, the white colored object in the center of the picture, first attracted the attention of Mr. Cassinat to investigate the accumulation. As near as could be determined the skull and bones were those of a woman and appeared to be of considerable age. The shape and form of the cranium did not appear to be characteristic of the white race, being more like an Oriental or Indian. Unfortunately, no test for fluorescence of the teeth was made prior to turning the remains over to the local officers. By means of fluorescent color reaction under ultra violet light it would have been possible to determine more definitely the race.

What secret does this pack rat nest hold? In all probability the skull and bones were transported no great distance by the rodents, but it would be indeed interesting to learn its origin.

NEW FOSSIL DISCOVERY

The world's only practically complete specimen of the skeleton of a large prehistoric animal known to scientists as Homalodotherium has been added to the fossil mammal exhibits at Field Museum of Natural History, Chicago.

Installed with the reassembled skeleton is a model, one-fourth natural size, showing the rare and strange creature as evidence indicates it must have appeared when living, during Miocene, about 15 million years ago.

Homalodotherium was a Southern American animal, and the museum's specimen was discovered by Elmer S. Riggs, associate curator of paleontology, while leading an expedition to Patagonia. Previous to this discovery, very little was known of this species of animal, as only fragmentary specimens of the skull, foot and leg had been found. Homalodotherium is known to have been a sturdy, heavy-bodied, strong limbed animal, as tall as an ox, but shorter in neck and body. Its head was similar in proportions to that of certain extinct members of the rhinoceros family. It had grinding teeth fitted for feeding on vegetation.

The animal was entirely without tusks or horns as a means of defense. The forelegs were long, and the bones had the peculiar structure observed in animals that dig. The broad forefoot was armed with stout claws which clearly were used for digging. The hind legs were well adapted for supporting the animal while digging, and may have enabled it to rear upright to feed from trees also.

THE ROSEBURG METEOR

A. R. ALLEN Trinidad, Colorado

The course of the great meteor of May 8, 1936, that flashed across the sky of western Oregon has been charted by Dr. J. H. Pruett of the University of Oregon, for the American Meteor Society.

This great meteor, one of the finest and most spectacular ever seen in the Pacific Northwest, was witnessed by many persons. It was seen by observers in three states and by a ship at sea off the California coast.

Dr. Pruett states it first became visible (at night) at a height of about 60 miles over a locality a short distance east of Oakridge and descended at an angle of 30 degrees to the horizontal and disappeared at a height of about 10 miles above a point just southwest of the town of Riddle. Many observers at the town of Roseburg also reported the meteor. The meteor left a bluish train in the sky and several observers at Riddle reported the meteor increased in brilliance until the light became as bright as the eye could endure. To date no fragments of this meteor have been reported found.

METEORITE STUDIES

For some years there has been a wide and growing popular interest in the study of meteorites. Articles pertinent to these very scientifically valuable bodies from outer space have appeared at frequent intervals in these pages.

We are fortunate in securing the services of a prominent meteorite expert, John Davis Buddhue, to take editorial charge of all data published on this subject. Mr. Buddhue is well known to readers of the magazine, numerous of his excellent articles have been published here.

Mineral collectors and students of geology searching in the field for specimens are in a position to make finds of meteorites. Any suspected specimen can be sent to Mr. Buddhue, who will without charge make an examination of the material. This will include chemical and microscopic tests and of course it will be necessary to break or cut a portion from the mass submitted for examination. Specimens will not be returned unless accompanied by sufficient postage and other instructions. John Davis Buddhue is among the leading meteorite experts of the country and his reports and papers will appear from time to time in the pages of this journal.

CURRENT MAGAZINES

Every lapidarist both amateur and commercial will find it advantageous to subscribe to one or more current periodicals devoted to his interest. There are two well known publications in this field having National circulation, devoted to Minerals, Gems, Gem Cutting, and the allied sciences. You will find it of distinct benefit to subscribe to one or both of these publications and keep informed of progress.

(1) *The Mineralogist Magazine*, a National monthly publication, 702 Couch Building, Portland, Oregon. Price, $1.00 per year. A special gem cutting department is maintained in this magazine.

(2) *Rocks and Minerals Magazine*, a National monthly publication, edited and published by Peter Zodac, well known in the field of mineralogy. Address Peekskill, New York. Price, $2.00 per year.

JOLIET FIELD TRIP

On Sunday, May 1, the *Joliet Mineralogists* (Illinois) will hold their first 1938 outing, at the Indiana Dunes State Park. All mineral and geology "fans" of Illinois and Indiana are invited to join in a noon get-together picnic. In the afternoon a tour will be made over the dunes, and an experienced lecturer will explain the various geological formations. Come equipped with good walking shoes. For additional information, address Ben H. Wilson, Joliet High School and Junior College.

The difference of things alike **GEM-LORE** *The likeness of things different*

GEO. H. MARCHER :: 568 GOWER STREET :: LOS ANGELES, CALIF.

RUBIES MADE IN AMERICA

RECENTLY in Hoquiam, Washington there came to light 123 pieces of synthetic ruby boules. These were made in this town in 1904. Only two years previously, Verneuil, in Paris, announced to the world his sensational process by which they could be made on a commercial scale. And yet, in this humble little lumber town of Hoquiam, thousands of miles from the great jewelry centers, a project was started for the manufacture of synthetic ruby; involving thousands of dollars investment, only to "crack up", as the little boules were prone to do on removal from the furnaces.

From the meager information now available, a French chemist in Hoquiam, who had learned Verneuil's process before leaving Europe, was ambitious to launch the industry in America. Two wealthy lumbermen, Polson and Ninemire, became interested in his work, and furnished the capital. Soon, thereafter, a laboratory was provided and the special little furnaces were made and installed. Synthetic rubies of good quality were produced. Hopeful, enthusiastic, they planned to market their product thruout the country.

The magnitude of their difficulties, however, in establishing a gem manufacturing business in a lumber town so distant from their important potential customers, soon became evident. Even their cutting orders had to be sent across the continent to New York lapidaries, and then returned to Hoquiam before shipping East again to customers. Soon the work dwindled and stopped. After a time the equipment became dismantled and scattered. Only one little parcel of boules, obtained by the writer, now remains to testify to these strange events.

But what are these furnace rubies? And do such old ones differ from what are now being made?

Synthetic rubies at that time were commonly called "reconstructed." Befor Verneuil, demonstrated that they could be made of ammonium alum at a lower cost and of better quality, all furnace rubies were produced by melting together smaller rubies from the mines, in order to obtain larger sizes that were more valuable. These were correctly designated as "reconstructed rubies." This story persisted, culpably, carelessly, or innocently, in sales talks, long after reconstructed stones had vanished from the market. It was hoped, in repeating this tale, that the prospective purchaser would rank these artificial stones beside the more valuable rubies produced by nature, instead of with the cheaper imitations made in glass factories. The correct term "synthetic" is now pretty well established.

Coming back more definitely to the Hoquiam boules, their smallness of size was a characteristic of all that were made during the beginning of the industry. Cut stones made from these smaller ones are more readily distinguished as artificial rubies than those cut from larger boules, such as are produced today. The curved "flowage lines", which may be seen in all synthetic rubies, were formed concentric with the rounded sides of the boule. In stones from the outer part of a larger boule, such lines are more nearly straight, and their slight curvature renders them more difficult to distinguish

entirely straight "growth
nay be found only in natural
efinite decision is sometimes
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ise of the confusion of view
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le Hoquiam boules, if cut,
lines that are more sharply
n in rubies produced today.
erage weight for the entire
six carats, while those made
from fifty to two hundred
arats each. To describe the
in their respective dimen-
convey to some readers a
of size: The Hoquiams were
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hes in height, but the mod-
sually from one-half to one
meter, and from one to two
eight.
all of these little carrot-
stals broken? The internal
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all synthetic boules. When
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furnace, melting as it goes,
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layer. When the boule is
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has been prevented by the
the material. The resulting
warp is known as "internal
is causes nearly all of them
cooling and the remaining
as soon as grinding is begun.
ch breaks into only two
ich partially relieves the
further breakage is quite
ttle progress has been made
coming this difficulty.
e more bubbles in this Ho-
rial than in modern. Inas-
presence of bubbles serves
important means of dis-
synthetic from natural, they
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ning entangled with the

molten powder as it fuses on top of the growing mass. Improved technique has done much, however since 1904, to lessen the number of these tell-tale bubbles.

The interest attached to these old boules as specimens of what were made at the beginning of the industry, is better preserved by retaining their present form intact, instead of defiling them with modern lapidation, and thereby destroying some of their identity.

That ruby crystals could be made in a furnace is a discovery that marks an epoch in the history of gemstones. In relative importance it is second only to the discovery that diamonds could be cut and polished by means of their own dust. And whether we like it or not, synthetic stones have affected the use of natural stones to a greater extent than anything else in the entire history of gems.

COLOR SIMILARITY

To distinguished a blue topaz from an aquamarine, from observation of color alone, is difficult or impossible even by a gem expert. If the color of the aquamarine proves slightly greener than the topaz in one instance, it may be bluer in another. In other words, *both* stones display a similar variation of hue, which suggests that the same impurities may be responsible for the color in both gems.

To identify them definitely, it is necessary to resort to a more technical determination. If the stone is unmounted, its specific gravity could be taken; or if mounted its refractivity ascertained. Either test would separate these confusing stones. Aquamarine has a specific gravity ranging from 2.63 to 2.91 and refractivity of 1.577 and 1.583. Topaz ranges in gravity from 3.40 to 3.65 and indices of 1.62 and 1.63.

Both topaz and aquamarine are doubly refractive and therefore each has two indices of refraction. The familiar saturated solution of red mercuric iodide and potassium iodide has a specific gravity of slightly over three and would be ideal to instantly and easily separate these two stones. Topaz would sink, the other float on the liquid.

OREGON GEM STONES

(*Book Review*)

"*The Gem Minerals of Oregon,*" Bulletin No. 7, Oregon State Department of Geology, 704 Lewis Building, Portland, Oregon, is now available. Price, 10 cents, plus five cents postage.

This paper was written in response to a wide public demand for information on the gem mineral resources of Oregon. It is not intended as a technical description of gem stones, but rather as a record of the known occurrences of gem minerals within the state of Oregon. Bulletin No. 7 will be found especially valuable to the prospector as well as those desiring to collect gem minerals in Oregon.

In recent years the production and development of the lapidary industry in Oregon has more than doubled. The bulletin makes references to this new industry of the state. Dr. H. C. Dake is the writer of "*The Gem Minerals if Oregon.*" He presents information obtained on numerous field trips and long association with local gem stone cutters. The Bulletin consists of 24 pages and includes ten illustrations. Bulletin No. 7 is available through book and supply dealers or direct from the publishers, 704 Lewis Building. The booklet is being sold by the Oregon State Department of Geology at cost, and Director Nixon announces people residing outside of Oregon will be supplied as long as file copies remain.

SEATTLE GEM CLUB

On March 12th members of the *Seattle Gem Club*, journeyed to Tacoma, Washington to hold a meeting at the home of Walter Sutter and spend the afternoon and evening viewing the marvelous Sutter collections.

The Sutter fluorescent collection is one of the most outstanding on the Pacific Coast; most of the fine specimens are mounted in niches over the face of a lar front. The specimens are illum six-foot length Braun Fluoroligh tube. The jade and Oriental art also outstanding and hours are view them all.

The outdoor geological rock ga of considerable interest to the here are found huge massive spec every part of the world, sent to by his many friends. Some of th specimens were collected per Walter Sutter, during his seve in the Orient as an engineer. *Gem Club* members wish to ex thanks and appreciation to Walter his kind and generous hospital dull moment was experienced b group of visitors.

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